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Energy and Mines

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Summary of Investigations 1983, Saskatchewan Geological Survey

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FOREWORD

Nearly all geological projects in progress are reported on in this year's Summary of Investigations. These are complemented by related studies co-ordinated with the Universities of Saskatchewan, Regina and Windsor, Carleton University and the Saskatchewan Research Council. Thus this volume presents a cross-section of the public geological work done in the Province this year.

I take this opportunity to thank all contributors and the editors.

J. E. Christopher
Director

October, 1983

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NOTE: Asterisked reports have an accompanying map. A list of accompanying map titles is placed on the inside cover of the map package.

PRECAMBRIAN MAPPING INVESTIGATIONS

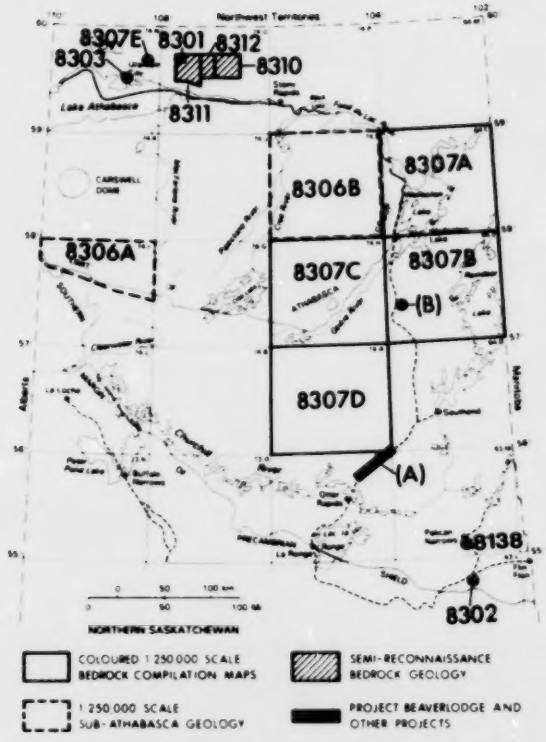


Figure 1 - Location of Precambrian bedrock mapping projects reported here. Numbers on map correspond to project numbers listed below.

Project No.	Area/ Short Title	NTS Sheet(s)	Project Leader(s)
Compilation Bedrock Geology, 1:250,000 scale[1]			
8307A	Wollaston Lake Area	64L	M.W. Thomas
8307B	Reindeer Lake North Area	64E	R. Macdonald and M.W. Thomas
8307C	Geikie River Area	74H	G.E. Ray[2]
8307D	Foster Lakes Area	74A	G.E. Ray[2]
Sub-Athabasca Basement Geology, 1:250,000 Scale			
8306A	Lloyd Lake Area	74F	C.F. Gilboy
8306B	Pasfield Lake Area	74I	C.F. Gilboy
Semi-reconnaissance Geological Mapping, 1:50,000 scale[3]			
8310	Oman Lake Area	74 0-10	B.P. Scott
8311	Nevins-Forsyth Lakes Area	part of 74 0	C.T. Harper
8312	Forsyth Lake (East) Area	74 0-11(E)	D.J. Thomas
8301	Oldman Lake Area	part of 74 0	R. Macdonald
Project Beaverlodge Studies			
8307E	Review Geology, Prince Lake Area	74N, part of 9	R. Macdonald and M.W. Thomas
8303	Martin Group Sedimentology	74N	H. Hendry
Other Projects			
8302	Hanson Lake Geochemical Project	63L	J.W. Gaskarth
8318	Pelican Narrows Project	63M	L.O. Craig
8308	Saskatchewan Shield Geochronology (Rb-Sr determinations)	-	K. Bell and J. Blenkinsop
8304	Zircon Isotope Geochronology	-	M.E. Bickford, W.R. Van Schmus and J.F. Lewry
Associated Studies[4]			
(A)	McLennan Group Meta-arkoses, McLennan-Jaysmith Lakes Area	74P	J.F. Lewry
(B)	Geochemistry of Meta-igneous Rocks, Combe Lake Area	64E	B.R. Watters

[1]All four mapsheets previously released in preliminary form were revised and published in colour during 1983.
[2]Former employee
[3]Possible final publication scale 1:100,000
[4]Not funded by Saskatchewan Energy and Mines during 1983-84

Introduction

by Robert Macdonald

This year the main thrust of Precambrian mapping was the reinstatement of a reconnaissance mapping program. This took place in the area north of Pond du Lac (NTS sheet 74 O). Four project leaders mapped adjacent areas in order to conserve charter flying resources. The terrain was also selected on account of proximity to Uranium City, where an effective expediting base is still available, and also because of the abundant clean rock exposure produced by recent bush fires. The areas mapped are underlain by units of the Nevins Lake block and the Train Lake domain (see Macdonald, this volume).

Compilation bedrock geology maps have been revised and published in an annotated full-colour form for four map-sheet areas. In order to expedite production, the maps were printed from laser scanning of hand-coloured originals prepared in pencil.

This is the final operational year of the Sub-Athabasca Geology project. Two more 1:250,000 scale maps are presented here in preliminary form; the remainder are due to be released on open file later in the year. The geology of the basement underlying the Athabasca Group is also being published in final form on the maps of the compilation bedrock geology series.

"Project Beaverlodge", a program set up last year to review the geology of the mineralized greater Beaverlodge area, was continued with completion of the 1:20,000 scale mapping of the Nicholson Bay sheet (not reported here) and with a field investigation of the Prince Lake vicinity lying along the extension of the St. Louis fault. The Martin Sedimentology project (University of Saskatchewan contract) was initiated. This project will entail detailed studies of the sedimentology of the Martin Formation, Beaverlodge area in relation to tectonics and mineralization. Also not reported here is the start made on a compilation of the Beaverlodge area at 1:20,000 scale; this compilation is expected to be published or open filed at 1:50,000 or 1:100,000 scale.

University contracts often provide a high return for a modest outlay by the department. The Saskatchewan Shield Geochronology project (Rb-Sr determinations) continued with samples from the active reconnaissance mapping area north of Pond du Lac. The Geological Survey also became involved in a new geochronology project which uses the U-Pb (zircon) method. Determinations will be carried out at the University of Kansas, in liaison with the University of Regina.

The Hanson Lake Geochemical Project is reported together with the Flin Flon Base Metals Project under the Economic Geology program. Another project, a detailed study of an area near Pelican Narrows, was carried out by the University of Saskatchewan with partial support from the department.

Two papers presented here report on the activities of two informally associated researchers (see Projects A and B).

Project 8310

Reconnaissance Bedrock Geology: Oman Lake Area (NTS 74 0-10)

by B. P. Scott

The centre of the map area lies about 120 km east of Uranium City. Crystalline Precambrian rock is exposed in about 70 percent of the area. Access by water is provided by lakes which drain eastward to Fontaine Lake and the Grease River.

Lithology

Felsic gneiss (unit 1) is a medium-grained, light grey to light pink weathering rock with less than 10 percent disseminated grains of biotite and hornblende. A vague foliation is common, due to preferred orientation of mafic minerals. Interbands of hornblende gneiss are common, but biotite gneiss bands are less common. Where hornblende and biotite content is greater than 10 percent, the felsic gneiss grades into light grey hornblende gneiss (subunit 2a) and semipelite (subunit 4a) respectively.

In general, the felsic gneiss is progressively granitized (subunit 1a) from west to east, attaining a coarser grain and exhibiting vague contacts with granite towards the east. Quartzite (subunit 1b) bands, light grey to rusty weathering, are common within felsic gneiss in the Miller Lake synform. Garnet comprises up to 90 percent of subunit 1b, with large amounts of iron oxide mineral. Garnetiferous felsic gneiss (subunit 1c) occurs in one outcrop near Hinchcliffe Lakes, near the southern boundary of the map area. Metaconglomerate (subunit 1d) contains well-rounded pebbles of diorite, 1 to 8 cm in diameter, in a white mafic-free arkosic matrix. Subunit 1d occurs west of the saddle in the Box Lake Synform.

Hornblende gneiss (unit 2) occurs in narrow bands within felsic gneiss and in bands and boudins several tens of metres wide. The latter are common in the inner portion of the Box Lake Synform. Unit 2 is weakly foliated, medium grained and light to dark grey-green weathering. The light coloured variety (subunit 2a), biotite-hornblende gneiss, contains about 15 to 20 percent hornblende and 5 to 10 percent biotite. The dark variety of hornblende gneiss (unit 2) contains more than 20 percent hornblende. Clinopyroxene and hypersthene are not present. Flattened clast-like forms, which may be relicts of a volcanic rock, occur in the northeast half of the Box Lake Synform.

Diopside gneiss (unit 3) occurs southeast of Rankin Lake. The rock is light green and medium to coarse grained. In one outcrop, a 1 m wide band contains 50 percent carbonate.

Pelitic rocks (unit 4) occur at Jantz Lake, Miller Lake and Box Lake. This unit contains greater than 15 percent biotite, is well foliated and grey weathering. Semipelite (subunit 4a) contains between 10 and 15 percent biotite. Andalusite occurs in a muscovite-rich zone of pelitic rocks on the south shore of Box Lake.

Fibrous sillimanite occurs in several outcrops in the southern part of the Box Lake Synform. Biotite garnet gneiss (subunit 4b) is located west of the southwest bay of Box Lake. Minor bands of garnetiferous quartzite occur locally. Coarse-grained biotite-feldspar gneiss is located in the northern part of the Box Lake Synform.

Granite (unit 5), which occurs in zones up to several hundred metres wide throughout the area, is pink, medium grained, biotitic and weakly foliated. It is conformable to semiconformable with the host rock with which it forms migmatites: subunit 5a, felsic gneiss migmatite; and subunit 5b, hornblendic gneiss migmatite. The granite fraction varies from 30 to 70 percent.

Unit 5 includes a granular remobilized rock which is little removed from granitized felsic gneiss (subunit 1a). This remobilized rock is massive, light grey, medium grained and feldspar-rich with less than 3 percent mafic minerals. It is common south and east of Box Lake and displays gradational to sharp contacts with younger pink medium-grained granite (unit 5).

In hornblende gneiss migmatite, the 'granite' fraction is locally tonalitic and contains appreciable coarse-grained hornblende.

Late aplite is common as small plutons in the northeast quadrant of the map area but elsewhere it occurs as narrow dykes. The aplite is light pink to reddish-grey weathering, fine to medium grained and contains less than 2 percent mafic minerals.

Late mafic dykes (unit 6) consist of biotite lamprophyre and diorite-gabbro. The former are in the minority and contain from 50 to 95 percent biotite.

Discussion

Metasedimentary units 1 to 4 have been folded around early southeast- to east-trending axial planes (F_1) (Figs. 1 and 2). A younger northeast-trending set (F_2) interferes with F_1, producing an elongate dome-and-basin pattern. This pattern is the product of orthogonal interference of two near-vertical phases of folds (Ramsay, 1967). In the southwest quadrant of the area, an F_1 fold trends in a westerly to northwesterly direction; it is crossed by the Box Lake and Miller Lake F_2 Synforms. Second-phase lineations plunge gently to moderately away from the saddles (Fig. 2). A mushroom-like form in the south part of the area could be caused by inclination of the F_1 axial plane. A north-trending set of folds (F_3) may be syn- or post-F_2.

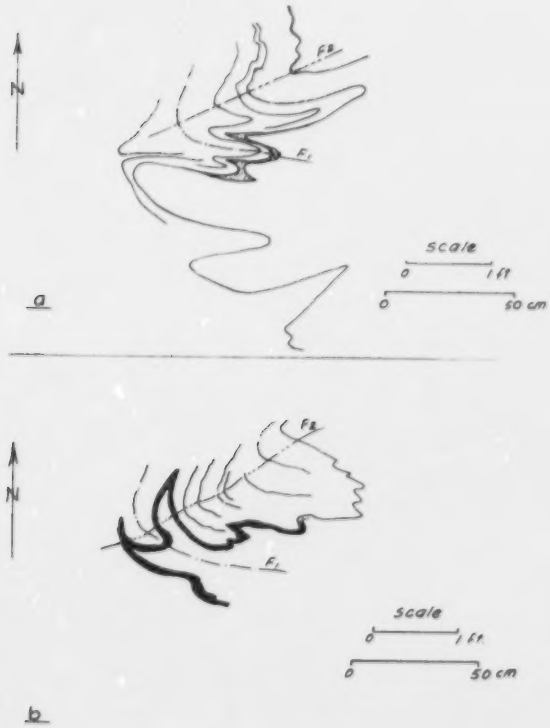


Figure 1 - Interference folding between first-phase (F_1) and second-phase (F_2) folds, in felsic gneiss. Interbanded lithologies include biotite gneiss (dotted areas) and hornblende gneiss (ruled areas); 1a, 4 km east of Fagan Lake; 1b, 2 km southwest of Fagan Lake.

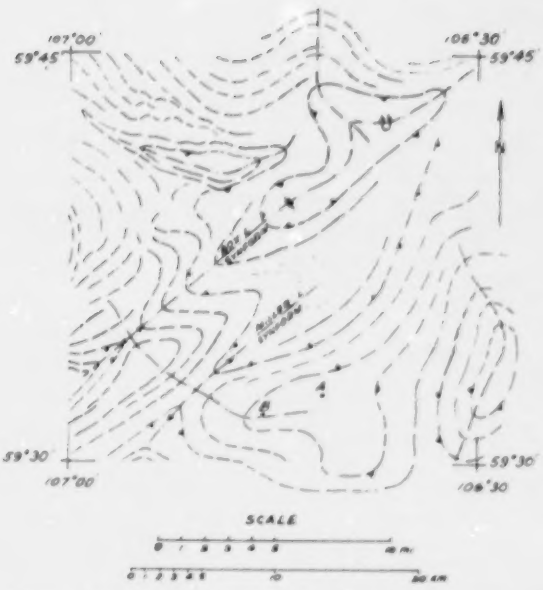


Figure 2 - Trend lines, Oman Lake area; saddles are developed where two second-phase folds (F_2, indicated by dashes and 2 dots) trend across a first-phase fold (F_1, indicated by dashes and one dot); a third-phase fold (F_3) interferes with the second-phase Box Lake Synform; points 'A' and 'B' refer to Fig. 1a and Fig. 1b.

Granite (unit 5) was probably emplaced syn-F_2, judging by the strong parallelism of elongated inclusions of supracrustal rocks (units 1 to 4) within the granite.

Medium- to high-grade metamorphism is indicated in pelitic rock (unit 4) by the presence of sillimanite and the local coarseness of the feldspar.

Cordierite and hypersthene have not been located. The absence of the latter probably indicates a prolonged period of retrograde metamorphism (i.e. post-granite (unit 5)).

Major faults trend north-south and east-west (GSC 1961). No sense of relative motion has been established, although left-hand movement is displayed on small-scale north-trending faults.

Economic

Zones of yellow carnotite (hydrous potassium-vanadium-uranium oxide) occur in coarse pegmatite veins within pelitic rocks, in the northeast portion of the Box Lake Synform. Several trenches have been made on the islands of Box Lake. Traces of molybdenite occur in the western islands (Cominco, 1969). The average uranium content of pegmatite sills found on South Island is 0.02 to 0.03 percent U_3O_8.

References

GSC (1961): Oman Lake (NTS 74010), aeromagnetics; Geol. Surv. Can., Geophys. Pap. 1224G, scale 1:63,360.

Cominco (1969): unpubl. geological and geophysical reports on Hird uranium property in Assessment File 74 O10-NE-0002, Sask. Energy Mines, Regina.

Ramsay, J.G. (1967): Folding and fracturing of Rocks; McGraw-Hill Book Co., New York, 568 p.

Project 8311

Reconnaissance Bedrock Geology: Nevins-Forsyth Lakes Area (Part of NTS 74 0)

by C. T. Harper

The geology of a 760 km^2 area centred about 65 km east of Uranium City has been mapped at a scale of 1:50,000. Access by float-equipped aircraft is excellent. The area is characterized by rugged terrain with excellent bedrock exposures across the south, but both relief and exposure diminish to the north. Recent forest fires which have swept all but the north-central part of the area have enhanced the exposure immensely. The mapped area is included in the 1:250,000 scale mapping of NTS area 74 0 by Baer (1968) and to the west joins the 1:63,360 scale mapping of Blake (1953). D. Thomas (this report) mapped the adjacent area to the east and R. Macdonald (this report), the northwest corner of the Nevins Lake (east) area.

The generally southeast-striking Oldman-Bulyea Lakes Shear Zone crosses the area diagonally and represents a possible extension of the St. Louis Fault (Fig. 1). Between Oldman and Willson Lakes the shear zone splits into many splay faults, the major ones being shown in Fig. 1. This major tectonic feature divides the area into two regions, which have distinctive lithological and metamorphic characteristics.

South of the Oldman-Bulyea Lakes Shear Zone

This region is characterized by granulite facies grade gneisses which become progressively retrometamorphosed to amphibolite facies towards the Oldman-Bulyea Lakes Shear Zone (Fig. 1). The majority of the rocks are feldspathic gneisses with minor pyribolite/amphibolite, iron formation, early metamorphosed mafic dykes, white pegmatites and numerous unmetamorphosed lamprophyre dykes. In the vicinity of the Oldman-Bulyea Shear Zone, pink granite sills and dykes intrude the retrograded gneisses and late lamprophyre dykes.

Feldspathic Gneisses (Unit F)

The feldspathic gneisses include garnet-feldspar gneiss (Fa), graphitic sillimanite-garnet-feldspar gneiss (subunit Fb), 'Schlater Lake-type' garnet-quartz-feldspar gneiss (subunit Fc), and hypersthene-feldspar gneiss (subunit Fd). Minor apatite-rich garnet-quartzofeldspathic gneiss and rare interlayers of calc-silicate rocks also occur.

Garnet-feldspar gneiss (subunit Fa) is commonly coarse grained, well layered, white, grey and locally pink weathering. Layers containing a little disseminated graphite are rusty weathering. The gneisses typically contain 20 to 30 percent garnet, but some layers, generally less than 20 cm thick, contain up to 80 percent garnet accompanied by quartz. The garnets range from several millimetres to 6 cm diameter. The feldspars typically weather chalky white but are waxy, grey, green or yellow on fresh broken surfaces. In unretrogressed areas quartz, which generally comprises less than 20 percent of the rock, is clear, grey or white but is markedly blue in retrogressed rocks. Streaky, ribbon and rod-like quartz is common near the major shear zone and splay faults, where it produces a pronounced penetrative linear fabric. Hypersthene and ilmenite occur locally. Yellow monazite grains have been noted in places where ilmenite is abundant. Biotite is common and increases markedly in the retrogressed rocks, where it forms pseudomorphs after garnet and hypersthene. Apple green apatite is also common (1 to 2 percent) in retrogressed zones, although it may not itself be a retrograde mineral. The apatite occurs as scattered tiny prismatic crystals a few millimetres to 1 or 2 cm long and in aggregate masses as much as 10 cm long and 5 cm wide. Rarely the apatite forms 20 to 80 percent of layers up to 20 cm thick, in zones 30 to 60 m thick. These layers may represent metamorphosed phosphorite deposits.

Garnet-feldspar gneiss is interlayered on both a small and large scale with hypersthene gneiss, with both sharp and gradational contacts (Plate 1A). White anatectic quartz-feldspar±garnet±hypersthene segregation pegmatite is locally abundant as lit-par-lit bodies which are axial planar to small-scale and outcrop-sized folds.

Graphitic sillimanite-garnet-feldspar gneiss (subunit Fb) occurs around Rose Lake and in the southwest corner of the area. It is distinguished from the garnet-feldspar gneisses (subunit Fa) by a generally finer grain size, finer lamination, more common graphite (as much as 10 percent), and general but not ubiquitous rusty weathering. Sillimanite occurs in many layers as coarse prismatic crystals as much as 1 cm long and

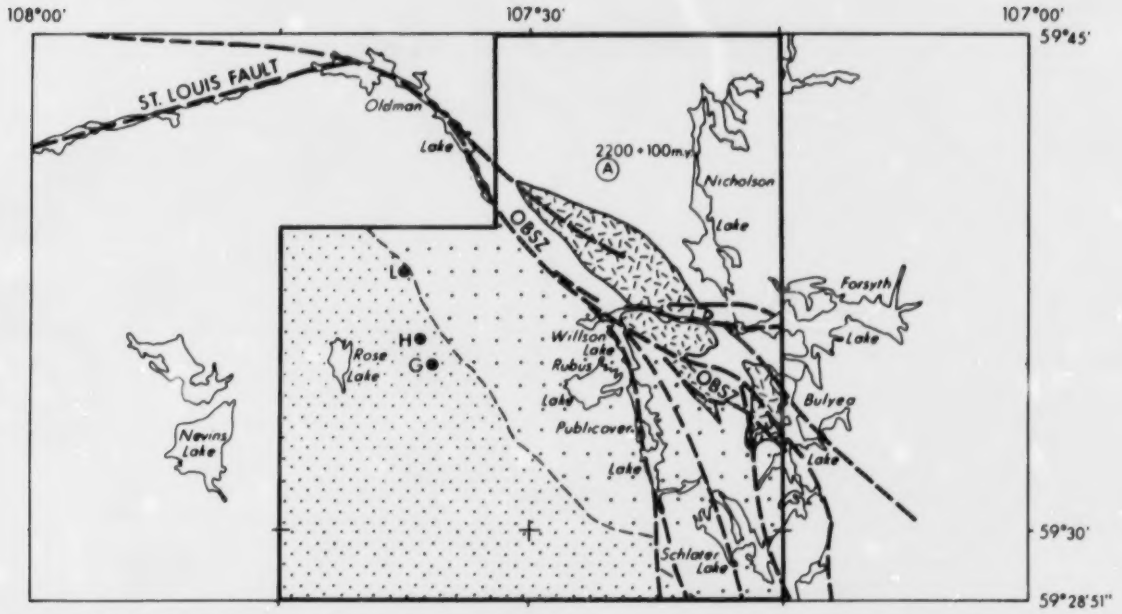


Figure 1 - General geological features of the area between Nevins and Forsyth Lakes. Key: close dot patterns, dominantly granulite facies; open dot pattern, granulite facies with amphibolite facies overprint; blank, amphibole facies; random dashes, zone of granite emplacement. The possible extension of the St. Louis Fault into the area as the Oldman-Bulyea Lakes Shear Zone (OBSZ) is shown. The dashed line marks the southern limit of extensive regional retrogression of the gneisses south of OBSZ. The location of a Rb-Sr isochron age of 2200±100 Ma for Beck's (1969) 'Older Granite' is shown, as are the locations (●) of samples collected for Rb-Sr geochronology. G, garnet-feldspar gneiss; H, hypersthene feldspar gneiss; L, lamprophyre.

in pods up to 30 cm long by 10 cm wide. In the southwest, dark blue and blue-grey cordierite porphyroblasts occur in felsic segregation pods and also accompany either sillimanite or garnet. Garnet is ubiquitous, as in subunit Fa, but in some very feldspathic rocks forms less than 5 percent of the rock. Quartzite, feldspathic quartzite and sulphide iron formation occur along the creek northwest of Rose Lake and in the extreme southwest corner of the area. A few hypersthene-feldspar gneisses are interlayered with this group of gneisses.

'Schlater Lake-type' garnet-quartz-feldspar gneisses (subunit Fc) occupy a basin-shaped structure at Schlater Lake in the southeast corner of the area mapped. These rocks are moderately to strongly retrogressed and the garnet is commonly replaced by biotite pseudomorphs. Layering is thin (generally less than 4 cm thick) and grain size varies from medium to coarse. They exhibit rusty weathering (due to less than 1 percent graphite) and contain ubiquitous garnets (3 to 4 mm in size), as well as apatite and muscovite. More siliceous than either of subunits Fa or Fb, they contain an average of 30 percent and exceptionally 50 percent quartz. Minor interlayers of fine-grained ($\leq$0.5 mm), equigranular feldspathic quartzite exist. The feldspar in these layers is commonly a pale yellowish-green colour, possibly indicating saussuritic alteration. A few thin, retrogressed hypersthene-feldspar gneiss layers are present locally. Subconcordant to discordant white pegmatites (subunit Pb) are present along the western and northern sides of Schlater Lake.

Hypersthene-feldspar gneiss (subunit Fd) is most abundant through the central part of the region. This subunit includes felsic to mafic rocks which are fine to very coarse grained, well layered to nearly massive and quartzose (less than 15 percent) to quartz-free. The felsic varieties, which tend to be more quartzose, are white to pale brown, slightly rusty where graphite is present, typically well foliated, and coarse grained (3 to 4 mm). Brown-weathering hypersthene, which comprises 20 percent or less of these rocks, is in places accompanied by garnet in equal or subordinate amounts. Feldspar weathers chalky white to grey but is

waxy, grey, green or yellowish on fresh surfaces. Ilmenite is a common and locally abundant accessory (up to 20 percent). The most common mafic type is a fine- to medium-grained (1 to 2 mm), rarely coarse-grained, equigranular, poorly foliated, brown-weathering rock which contains 30 to 60 percent hypersthene, white plagioclase, no quartz, and pale green diopside and dark amphibole in places. Felsic segregations (quartz and feldspar) contain very coarse (5 to 10 cm) porphyroblasts of hypersthene and dark red garnet. Biotite, which is usually present even in the freshest samples, is considered to be retrograde. With increasing retrometamorphism the hypersthene gneisses are replaced by biotite and hornblende, producing grey to dark grey and dark green gneisses. Fractures across mafic hypersthene-feldspar gneisses develop narrow to irregular zones that are retrogressed to green-black hornblende. In places the mafic hypersthene-feldspar gneiss alternates with white, nearly mafic-free quartzofeldspathic rocks. This interlayered sequence resembles shale-sandstone or felsic-mafic tuff sequences.

Iron Formation (Unit IF)

Thin ribbons of sulphide (s), silicate (g) and oxide (o) facies iron formation, commonly less than 3 m and rarely up to 30 m thick, are interlayered with the feldspathic gneisses. A facies change occurs from west to east, with sulphide facies in the more graphitic feldspathic gneisses (subunit Fb) west of Rose Lake and in the extreme southwest near Schaffer Lake. Oxide and silicate facies iron formation commonly coexist east of Rose Lake. Oxide facies is best developed in the central and south-central areas, whereas the silicate facies extends to the northern and eastern limits of the region but with diminishing size and frequency. It is not certain whether the iron formations represent a single but repeated horizon or whether several horizons are present.

Sulphide facies iron formation (subunit IFs) is a very strongly iron stained, well-layered rock which contains less than 10 percent disseminated to weakly banded pyrite-pyrrhotite mineralization within a graphitic sillimanite-biotite-garnet-quartz-feldspar gneiss. Graphite commonly comprises 1 or 2 percent of the rock and exceptionally 10 percent with flakes up to 5 mm across. Oxide facies iron formation (subunit IFo), which is reddish-brown to purple weathering due to earthy to specular hematite, is interbanded in places with quartz and garnet and also occurs in massive form. Magnetite is generally absent or only of minor importance but was noted as the dominant mineral in one occurrence. The presence of ilmenite indicates that the iron formations are titaniferous. In most places the massive specular hematite contains abundant equant garnet porphyroblasts 2 to 4 mm in diameter.

Oxide facies iron formations are associated and interlayered with the silicate facies (subunit IFg), consisting of abundant (20 to 80 percent) dark red, generally equigranular (2 to 3 mm diameter) garnet which is either associated with clear to bluish quartz or pyroxene, amphibole, biotite and ilmenite (rarely magnetite). The layers are commonly zoned with quartz-garnet margins and garnet-pyroxene-amphibole centres.

Pyribolite/Amphibolite (Unit M)

Pyribolite/amphibolite rocks are best exposed between Rubus and Willson Lakes and extend down through Publicover Lake toward Schlater Lake. Some thin bands, which in places are boudinaged, occur east and west of Publicover and Schlater Lakes, but are rare further west. Most of these rocks have been retrograded to amphibolite facies, but relict hypersthene-bearing patches exist in most occurrences. The pyribolites are typically light to dark brown and greenish-brown, whereas the retrogressed equivalents are dark green to black. Most of the rocks are knobbly weathering, coarse to very coarse grained, layered to massive, generally poorly foliated and typically contain more than 50 percent mafic minerals. Plagioclase is the chief felsic component. Dark green to black hornblende is common, as is dark brown biotite, but in some 'ultramafic' varieties the rocks appear to have undergone further retrogression and now consist of actinolite, chlorite and biotite. At several localities around Rubus Lake, preservation of primary volcanic structures is suggested by pillow-like features in probable ultramafic lavas, and ovoid to elongate inclusions up to 30 cm long, typically of more felsic composition than the host, suggest a possible pyroclastic origin. In many places the pyribolite/amphibolite unit is interlayered with fine- to medium-grained, white to pink quartzofeldspathic rocks of granitic composition. These interlayered rocks resemble felsic volcanics or arkosic sediments, suggesting either a basalt-rhyolite or a basalt-arkose association.

Early Mafic Dykes (Unit D)

Dark grey, greenish-grey, brown and dark green dykes, perhaps originally of diabase

composition, intruded the above gneisses (Plate 1B) prior to the granulite facies metamorphism, as indicated by the presence of metamorphic hypersthene. These dykes are locally folded, intruded by younger biotitic white pegmatites and have undergone amphibolite facies retrogression. The dykes vary from 0.2 to 20 m in width and generally trend 340 to 360°, less commonly 050°. The rock is fine to coarse grained (1 to 3 mm), weakly foliated, and contains 60 to 80 percent mafic minerals, including hypersthene, dark green pyroxene and black hornblende; the remainder is plagioclase. Zonal to patchy retrogression to greenish-black weathering amphibole occurs along cross-cutting fractures, whereas along the contacts with country rocks retrogression commonly results in a bright green weathering amphibole (± chlorite).

White Pegmatites (Unit P)

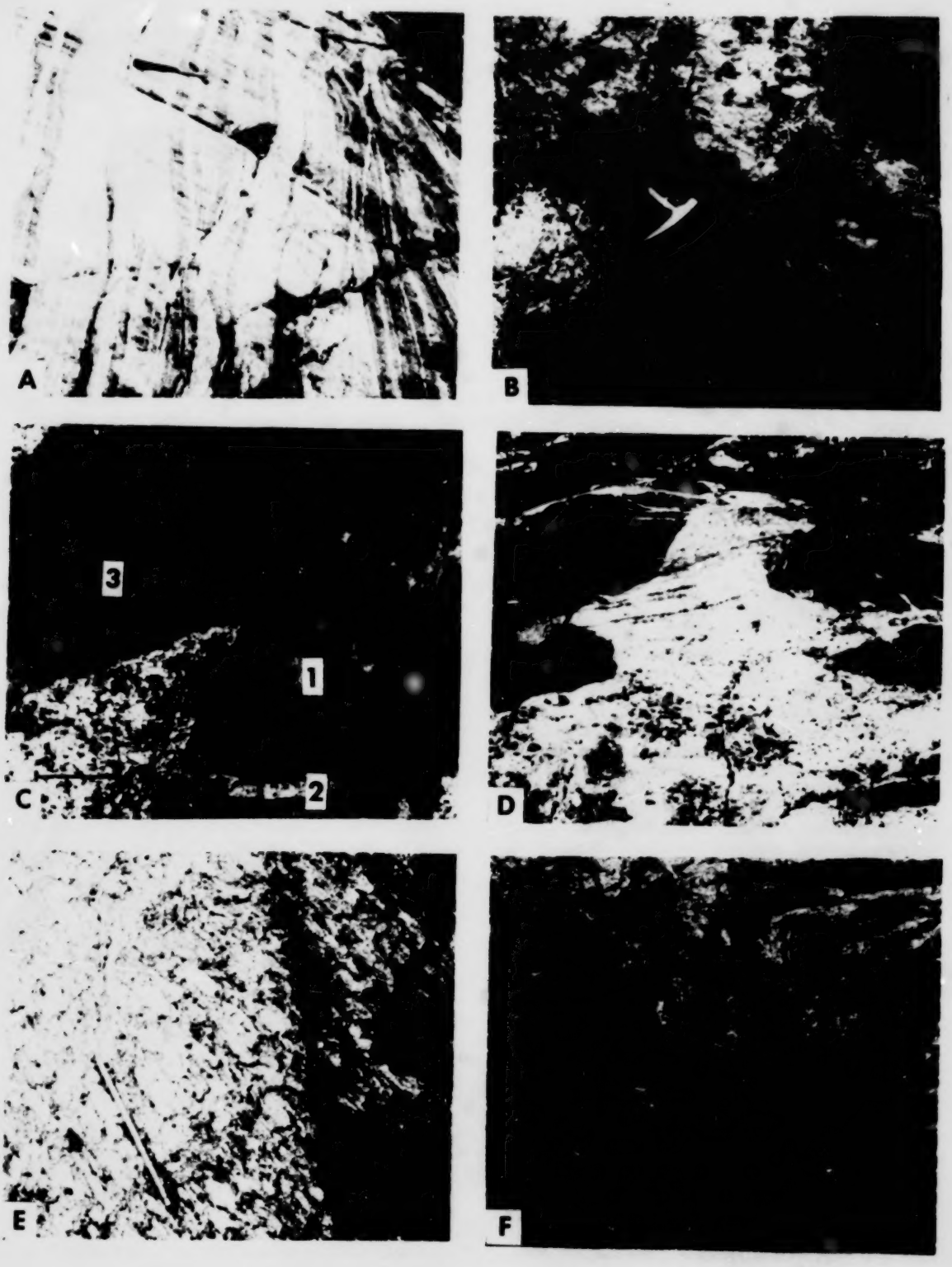
Generally straight-sided, white-weathering, steeply dipping biotite-muscovite pegmatite dykes (subunit Pa), 0.2 to 15 m wide, intrude all the above rocks. They are rarely of mappable dimension, but areas of abundance are indicated on the accompanying map. The pegmatite is characterized by very coarse books of biotite (from 2 or 3 cm to 50 cm in length), which comprise 10 to 30 percent of the rock. Muscovite is locally abundant (10 to 20 percent) and quartz averages 20 percent. Some of the pegmatite is radioactive. These pegmatites differ from earlier anatectic-type pegmatites in not containing garnet or hypersthene. They are not foliated except where sheared or retrograded, but in places appear to be the cause of local retrogression of the older gneisses. No preferred orientation was detected. In the area south of the Bulyea Lake granite as far as the west shore of Schlater Lake, a different suite of white pegmatites (Pb) occur as shallow dipping, locally folded, sill-like bodies up to 30 m thick in which biotite is rare or absent. Instead, books of muscovite and yellowish, sheaf- to horsetail-like aggregates of muscovite, quartz and possibly tremolite occur. These aggregates vary from a few centimetres to 30 and 40 cm long by 5 to 10 cm wide. Their significance and origin is uncertain.

Lamprophyre Dykes (Unit L)

Pink, red, brown, green, grey and black weathering, generally subvertical lamprophyre dykes, which range from 2 cm to 15 m thick, intrude all of the above rocks south of the Oldman-Bulyea Lakes Shear Zone. The lamprophyres have a pitted weathered surface where biotite phenocrysts preferentially weather out. The rocks are fine to coarse grained (1 to 5 mm) and massive. They consist essentially of 60 to 80 percent pink to red potash feldspar, 20 to 40 percent black phenocrystic biotite (1 to 10 mm long) and some contain 10 to 20 percent black hornblende and/or a green amphibole or pyroxene. A few dykes display graded (cumulate-like) flow layering indicated by concentrations of feldspar crystals. Most dykes have a narrow chilled margin and many contain rounded to angular xenoliths of the country rocks. Many of the dykes split into two or more parallel or en echelon bodies, incorporating large blocks of the country rocks. Two major trends exist, the most prominent being northeast with the other at right angles to it and possibly younger. Many of the larger dykes can be traced for a kilometre or more and coincide with prominent airphoto linear features.

In the southwest at least three ages of lamprophyre emplacement are defined. The earliest dykes trend southwest; they are cut by pink, fine-grained, very feldspathic (less than 5 percent biotite) lamprophyre veins and both are cut by southwest- to west-southwest-trending dykes similar in composition but finer-grained than the first (Plate 1C). Some larger dykes are throughly brecciated and veined by the feldspathic lamprophyre. Elsewhere in this area the southwest-trending dykes are intruded by a younger lamprophyre which in most cases parallels the trend of the earlier dyke. The younger dyke has a well-defined chilled margin and is finer grained. At Haynes Lake a pair of southwest-trending lamprophyre dykes are cut and offset by shears related to the Oldman-Bulyea Lakes Shear Zone. In the same outcrop the dykes are intruded by a small stock of pink granite (G). In this same general area other lamprophyre dykes are sheared, drag folded and intruded by late pink granite pegmatite adjacent to major fault and mylonite zones of the Oldman-Bulyea system.

Plate 1 - A) Interlayered garnet-feldspar and hypersthene-feldspar gneisses (darker layers); photo by W. Slimmon; B) Metadiabase cutting garnet-feldspar gneiss; hammer handle parallels gneissosity and hammer head marks contact with dyke; Pencil is aligned with axial plane of small-scale fold; dyke is locally retrogressed along fractures (dark rills); C) Three ages of lamprophyre dyke emplacement; scale bar is 10 cm; D) Gross migmatic character of amphibolite gneiss with abundant white granitic segregations all cut by late granite sheets; ruck sack is about 50 cm wide; E) Augeniferous biotitic-hornblende quartzofeldspathic gneiss; pencil is about 17 cm long; F) Mushroom- and boomerang-shaped fold interference patterns in quartzofeldspathic gneisses.


A
B
3
1
2
C
D
E
F

North of the Oldman-Bulyea Lakes Shear Zone

This region is characterized by amphibolite facies grade gneisses which show no evidence of having reached granulite facies conditions or having undergone extensive regional retrograde metamorphism. The dominant rocks are migmatitic quartzofeldspathic gneisses containing varying proportions of biotite and hornblende, with minor amphibolite and rare pelitic gneiss. A zone of granite emplacement parallels the Oldman-Bulyea Lakes Shear Zone (Fig. 1) and numerous smaller sheets and dykes of granite and pegmatite are scattered through the region.

Biotitic-Quartzofeldspathic Gneiss (Unit Q)

Quartzofeldspathic gneisses are pink to light grey, in places colour banded, well layered to nebulitic with abundant white, pink or grey 'sweaty' granitic segregations. They vary from fine grained (1 mm) and equigranular to coarse grained and porphyroblastic, typically contain 5 to 15 percent biotite, are locally hornblendic and in places grade imperceptibly into biotitic hornblende quartzofeldspathic gneiss (unit H). The biotite quartzofeldspathic gneisses include a few garnetiferous biotite-quartz-feldspar gneiss (subunit Qa) interlayers which contain as much as 20 percent garnet and 20 to 40 percent biotite. Interlayers and boudins of amphibolite gneiss (subunit HA) are also common.

In the vicinity of the larger granite sills and bodies the quartzofeldspathic gneisses are increasingly migmatized and an irregularly bordered, weakly foliated, white to pink granitic component is commonly developed. This granitic component is intruded by and incorporated as xenoliths within the younger granites and pegmatites.

Biotitic-Hornblende Quartzofeldspathic Gneiss (Unit H) and Amphibolite (Unit HA)

The biotitic-hornblende quartzofeldspathic gneisses (unit H) are similar to the biotitic quartzofeldspathic gneisses (unit Q) in colour, texture and general migmatitic character, but in this variety hornblende is the dominant mafic mineral. They also contain more numerous small pods, lenses and layers of hornblende-rich rock (80 to 90 percent hornblende, the remainder plagioclase).

The amphibolite (unit HA) is characteristically disrupted and extensively invaded by granitic material which produces a large-scale agmatitic structure (Plate 1D). East and north of Nicholson Lake two varieties are common. Hornblende-plagioclase gneiss (subunit HA1) is a dark grey, fine- to medium-grained, equigranular, poorly foliated type. It commonly occurs as 1 to 2 m thick boudins and is cut by numerous white anatectic granitic pegmatite veins and euhedral quartz-chlorite veins. Hornblende comprises 40 to 50 percent of the rock. Garnet (1 to 2 mm) averages less than 5 percent but locally comprises as much as 40 percent of the rock.

The other type is a spotted amphibolite (subunit HA2) which is dark grey to black with white or red spots, coarse grained (2 to 10 cm), poorly foliated and contains 40 to 50 percent hornblende. Three types of spots are common: 1) white plagioclase, 2) cores of red garnet with rims of white plagioclase and, less commonly, 3) white plagioclase with small hornblende cores. The spots vary in diameter from 0.1 to 1 cm and exceptionally to 2 cm, and generally comprise 40 to 50 percent of the rock. In places the spots are distributed in zones (particularly in smaller boudinaged segments), with garnet-free plagioclase spots along the margins, gradually becoming more garnetiferous and larger towards the centre of the boudin. Size gradations appear to occur in some of the larger bodies, suggestive of flow amygdules, but generally the spots appear to be of metamorphic origin.

The spotted amphibolite commonly grades into a coarse-grained (3 to 5 mm) dioritic to gabbroic amphibolite (subunit HA3) which lacks garnet. Hornblende comprises 40 to 60 percent and plagioclase the rest of the rock. This variety is more common west of Nicholson Lake.

Granite (Unit G)

Pink, generally massive (but weakly foliated locally), fine-grained to porphyritic granite and granite pegmatites are the youngest intrusive rocks of the area, with the pegmatites being the youngest phase. The finer grained (2 mm) type contains less than 5 percent biotite, 30 percent quartz and less than 10 percent plagioclase, the remainder being pink potash feldspar. The porphyritic variety contains 30 to 60 percent potash feldspar phenocrysts from 0.2 to 1 cm long, which are in places preferrentially aligned. Biotite is more abundant, comprising up to 15 percent of the rock and the matrix is coarser grained than in the finer grained granite. Quartz, plagioclase and potash feldspar are present in the matrix. The pegmatites are dominantly potash feldspar, quartz and less than 5 percent biotite. The granites contain xenoliths which are aligned in some places.

The granites and pegmatites occur as dykes and sills from a few metres to several hundred metres thick and as larger stocks such as the Willson Lake and Bulyea Lake bodies. The Bulyea Lake granite has a finer grained strongly foliated margin and is progressively more porphyritic inwards where it is less well foliated. In the northeast, granite and pegmatite occur as dykes axial planar to large regional folds and as sills subconcordant to the gross litholigical layering. Around the margins and within the larger granite bodies are sheeted complexes of interdigitating gneiss and granite (designated unit GQ or GH depending on the nature of the gneiss). Larger gneissic bodies in the granites are indicated on the accompanying geological map.

An apparent spatial and possibly temporal relationship between the zone of granite emplacement and the Oldman-Bulyea Lakes Shear Zone is suggested by their proximity and parallelism. Post-granite faulting has, however, produced local chloritic and epidote-filled breccia and fault offsets, and developed mylonitic fabrics (eg. Bulyea Lake granite) in the granites.

Rocks Associated with the Oldman-Bulyea Lakes Shear Zone

The shear zone and its subsidiary splay faults are principally defined by mylonite (unit My) and by mylonitic (my) and augeniferous (aug) structures in a variety of rock units. The proximity to the various splays and the main shear zone is marked by the progressive development of streaky foliation, a stronger penetrative regional foliation, augen structure, chloritized and epidote-filled fractures and breccias, mylonitic gneisses and mylonites. Many of the splay faults are defined by narrow zones of mylonite, 1 to 3 m wide, which truncate the gneissic foliation. The main shear zone affects a much broader zone up to 2 km wide in places. All of the observed mylonites dip southwesterly.

The typical mylonite is green (chloritic), cherty and finely laminated, but pink (felsic protolith) and black varieties also exist. The cherty mylonites are commonly interlayered with less mylonitized rocks and develop tight S- and Z-shaped folds. Later movements along these zones results in brecciation of the mylonite accompanied by epidote-filling of fractures. In mylonitic gneisses, substantial recrystallization and grain-size reduction has occurred, but the original rock type is still generally recognizable. In some places, particularly along Willson Lake and the west end of Forsyth Lake, the mylonitic gneisses are noticeably red and contain chlorite and epidote. They are similar to the fault related red gneisses described by Koster (1965) and are identified by an additional prefix 'r', for example rmyH.

The apparent systematic break-up of feldspathic layers into 0.5 to 2 cm long augen and concommittant shearing of the mafic component has produced a strongly foliated and lineated augeniferous gneiss (Plate 1E). The mafic content of these gneisses tends to be greater than the unstrained protolith. They form a nearly continuous belt across the area parallel to the main shear zone.

Structure

South of the Oldman-Bulyea Lakes Shear Zone, outcrop patterns suggest the presence of complex fold interference patterns. The earliest folds appear to be overturned generally east-striking isoclines with shallow, southwesterly-dipping axial planes. These were refolded about generally upright northwest-trending folds, and by younger, more open, upright, northeast-striking folds. The resulting interference patterns vary from dome-and-basin (Type 1B, Ramsay, 1967) to mushroom-shaped (Type 2H, Fig. 10-13, Ramsay, 1967).

A strong penetrative gneissic foliation parallels the gross lithological layering. A younger generally northeast-striking penetrative foliation and southwest-plunging lineation is increasingly developed towards the Oldman-Bulyea Lake Shear Zone. Drag folding caused by faulting is common, and recognizable on a regional scale (e.g. Drag Fold Lake and Schlater Lake). The Oldman-Bulyea Lakes Shear Zone and its splays are probably the oldest faults, but have had recurrent movements. They may represent a major thrust and lesser thrust slices that dip southwest to west. South of this zone three major sets of faults, which are all generally subvertical, are recognized. The earliest appear to be arcuate and trend north to northwest. These are offset by northeast-striking faults which appear in turn to be cut by a west-northwest set (e.g. Rose Lake Fault). All of these faults are characterized by reddening of the adjacent country rocks, chloritization, brecciation, and filling of fractures and breccias by epidote. The lamprophyre dykes occupy many of the northeast and northwest fractures.

In the region north of the Oldman-Bulyea Lakes Shear Zone, outcrop patterns of the

supracrustal gneisses are less well defined but show a similar pattern of folding to that south of the shear zone. Small-scale mushroom- and boomerang-shaped fold interference patterns indicate an early period of overturned isoclines with shallow southwesterly dips which are refolded about upright northwest-striking axes (Plate 1F). The most prominent regional folds belong to the open upright northeast-striking system. Again, as observed south of the shear zone, a strong southwesterly-plunging lineation becomes more intense towards the Oldman-Bulyea Lakes Shear Zone, suggesting a relation to faulting. Prominent fault sets north of the shear zone (in probable order of development) are northwest, north and east-northeast. These faults are also characterized by reddening of the country rocks, brecciation, chloritization and epidote-filling of fractures.

Metamorphism

South of the Oldman-Bulyea Lakes Shear Zone, the regional metamorphic grade is granulite facies with hypersthene as the diagnostic mineral. Sillimanite is present in the west and cordierite in the extreme southwest, suggesting a lowering of the grade in that direction. Cordierite may also be younger. The granulite facies rocks are locally retrogressed to the amphibolite facies adjacent to the biotitic pegmatites and to greenschist facies along most faults. A regionally developed amphibolite facies retrograde metamorphism is progressively more extensive towards the Oldman-Bulyea Lakes Shear Zone. Here garnet is completely and pseudomorphically replaced by biotite, and hypersthene by a mixture of biotite and/or hornblende, or other amphiboles. Many of the mylonites which cut the retrograded granulite facies rocks are still in the amphibolite facies, whereas the main shear zone is in the greenschist facies.

North of the Oldman-Bulyea Lakes Shear Zone, the gneisses have apparently only undergone an amphibolite facies metamorphism. Hornblende, biotite and garnet are characteristic. Sillimanite and cordierite are apparently absent. In contrast to the southern region these gneisses are more migmatitic and anatexis is widespread. A regional retrometamorphic event is not indicated. The gneisses are overprinted, however, by greenschist facies minerals adjacent to the Oldman-Bulyea Lakes Shear Zone and several other major faults.

Age Relations and Geologic History

The gneisses north and south of the Oldman-Bulyea Lakes Shear Zone appear to belong to two distinct supracrustal assemblages, the older of which is not entirely clear. On the basis of the metamorphism one might suspect that the granulite facies rocks are older, by virtue of the zone of amphibolite facies retrogression and the apparent single amphibolite facies event in the northern gneisses. However, some geochronologic studies of Archean terrains reported in the literature (e.g. Collerson, 1983) have demonstrated that terrains recording only amphibolite facies metamorphism yield the oldest ages. Adjacent granulite facies terrains, with which they share a faulted contact, yield younger ages because of a younger granulite facies event. Such a sequence of events appears to be recorded in the region south of the Oldman-Bulyea Lakes Shear Zone. Here the early mafic dykes (unit D) were emplaced into an already highly deformed and high-grade (at least upper amphibolite facies) metamorphic terrain which possessed a well-developed gneissic texture and lit-par-lit anatectic granite segregations. These dykes and the gneisses were subsequently metamorphosed at the granulite facies. In view of the similar structural patterns north and south of the shear zone it is possible that the pre-mafic dyke metamorphic event in the southern region is equivalent to the amphibolite facies metamorphic event in the northern region.

The regional retrometamorphism of the granulite facies rocks appears to be related to the faulting event which formed the Oldman-Bulyea Lakes Shear Zone and which brought the granulite facies and amphibolite facies terrains into juxtaposition. Further retrogression to greenschist facies occurred with recurrent movement along these faults.

Beck (1969) obtained a four point Rb-Sr isochron age of 2200±100 Ma from four widely separated samples of his 'older' granites. One of these samples was collected from a granite body 3 to 4 km west of Nicholson Lake (Fig. 1). These granites are considered to be the youngest rocks in the area mapped and thus, if this age is correct, all the other rocks are older and could presumably all be of Archean age.

In an effort to help clarify some of the above problems, sample suites of the garnet-feldspar and hypersthene-feldspar gneisses and the lamprophyre dykes from the southern region (Fig. 1) were collected for Rb-Sr isochron geochronology (see Bell, this report).

Table 1 - Tentative Geologic History of the Area Between Forsyth and Nevins Lake.

Approximate Timing	Events	
Pleistocene to Recent	Glaciation; deposition of glacial deposits; erosion	
Precambrian		
Post-Hudsonian Orogeny	Uplift, erosion and peneplanation; recurrent fault movements	
ca. 1800 Ma	Hudsonian Orogeny; faulting, greenschist facies metamorphism	
	South of Oldman-Bulyea Shear Zone	North of Oldman-Bulyea Shear Zone
ca. 2200 Ma	Granite emplacement	Granite emplacement
	Faulting, formation of the Oldman-Bulyea Shear Zone?, regional retrograde metamorphism?	Faulting, formation of the Oldman-Bulyea Shear Zone?
	Faulting, lamprophyre dykes	
	Faulting, white bi ± musc pegmatites	
		High grade metamorphism, ? multiple deformations
2500 Ma?	Granulite facies metamorphism	
		Sedimentation and volcanism
	Faulting, diabase dykes	
	High-grade metamorphism, multiple deformations	
	Sedimentation and volcanism	

The general geologic history of the area is summarized in Table 1.

Economic Geology

The area has seen sporadic exploration activity since the early 1900s sparked by the discovery of nickeliferous pyrrhotite occurrences in 'noritic' rocks (probably mafic to ultramafic metavolcanics), gold-bearing quartz veins and a falsely reported high-grade silver occurrence, all 40 to 60 km to the southeast (Camsell, 1916; Mawdsley, 1949; Beck, 1959; and Baer, 1968). From the 1950s to the present the main activity has been the exploration of radioactive occurrences. Within the area mapped, known mineralization includes iron formation, uranium, thorium, rare earth elements (REE), and traces of molybdenum.

Both sulphide and oxide facies iron formation occur in relatively thin bands of low economic grades. The sulphide facies occurs as pyrite and pyrrhotite (generally less than 10 percent by volume) and the oxide facies primarily as earthy and specular hematite in which magnetite is rare. The lack of magnetite makes the oxide facies impossible to detect with airborne magnetic surveys. Several small pits were found in the sulphide facies iron formation along the creek draining Rose Lake and the northward extension of this band at the south end of a small lake about 1.5 km southwest of Davidson Lake. To the writer's knowledge, neither facies have been tested for their gold potential.

Airborne and ground radiometric surveys, and prospecting have located numerous radioactive occurrences in the area. Most have been found to consist of minor concentrations of uraninite in pegmatitic and granitic rocks, but a few occur along the margins of lamprophyre dykes. During the course of the present mapping yellow secondary uranium 'bloom' was observed at a number of localities associated with white biotite

pegmatites (subunit Pa) and less commonly with granitic rocks adjacent to the Oldman-Bulyea Lakes Shear Zone.

In 1949 the Neiman Lake Uranium Prospecting Syndicate obtained assay values of 0.09 to 0.91 percent U_3O_8 from grab samples collected from three trenches excavated across the radioactive contact between graphitic garnet-feldspar gneiss (subunit Fb) and a northeast-striking, black-weathering, biotite-rich lamprophyre dyke (unit L). The zone, which is located along the creek draining Rose Lake, was traced for about 40 m (Assessment File 740-12-SE-0006, Saskatchewan Energy and Mines, Regina).

Two unreported trenches, about 750 m west of the westernmost bay of Haight Lake, reveal highly radioactive and very coarse porphyroblasts of biotite (up to 0.5 m long), in a white pegmatite (subunit Pa). Yellow uranium bloom is also present. A third trench, 100 m further west, exposes two white pyritic and biotitic pegmatites, as well as strongly retrograded garnet-feldspar gneiss (subunit Fa). The more pyritic of the two pegmatites contains tiny (< 1 mm) uraninite crystals and possibly zircon and/or monazite.

An airborne radiometric survey carried out in 1968 for Trans Canada Resources Ltd., followed by prospecting of the anomalies, led to the discovery of a REE-bearing monazite occurrence, located about 1 km northeast of Schaffer Lake. The occurrence is confined to a 5 m wide zone traceable for 600 m. Samples obtained from trenches excavated in 1970 yielded assays of 0.1 to 15.7 percent $(RE)_2O_3$, 0.1 to 2.31 percent ThO_2, 0.002 to 0.014 percent U_3O_8 and a trace of gold. Spectrographic analyses of two samples by Crest Laboratories (B.C.) Ltd. indicated the presence of the following REE (in decreasing order of abundance): lanthanum, cerium, gadolinium, lutetium, terbium and ytterbium. Trace amounts of scandium and yttrium are also recorded (Assessment Files 740-5-NW-0046, 740-5-NE-0038, 0053 and 0059). The round yellow grains of monazite (1 mm diameter) occur in reddish-brown hypersthene-garnet-feldspar gneiss. This gneiss occurs in an 8 to 10 m wide layer which is altered (feldspathized?) and ilmenite-rich (10 to 50 percent by volume in places). Monazite locally comprises up to 50 volume percent of the rock and is closely associated with the ilmenite. The common occurrence of these minerals in heavy mineral beach sands (Cranstone, 1983) and the stratabound character of the mineralization suggest the occurrence is syngenetic. Several other minor occurrences of monazite-bearing, ilmenite-rich, garnet±hypersthene-feldspar gneiss were located during the present study. The remoteness of the REE occurrence and limited markets render it uneconomic at present.

Thirty kilometres northwest of the map area at Nisikkatch and Hoidas Lakes, rare earth elements are associated with allanite- and apatite-bearing veins in leucocratic gneisses (Hogarth, 1957; Koster, 1965; Dunn, this report). Although no such occurrences of this type are known within the present area, some very apatite-rich zones occur in the feldspathic gneisses. Some of these may represent metamorphosed phosphorites, another possible source of REE (Cranstone, 1983), but whether any are radioactive or contain REE is not yet known.

A few isolated flakes of molybdenite were found at several localities in late pink granite and pegmatite (G) dykes. None of the occurrences appear to be of economic significance.

Rocks described as norite (Cooke, 1937; Blake, 1955) host nickeliferous pyrrhotite deposits in adjacent areas. One such deposit, located at Dinty Lake about 7 km west of the map area, contains an estimated 1.36 million tonnes of ore grading 0.6 percent nickel, with trace amounts of chalcopyrite, sphalerite and molybdenite. These 'norites' are probably equivalent to the pyribolite/amphibolite (M) unit of this report and thus have the potential of hosting Ni-Cu and perhaps gold mineralization. The pyribolite/amphibolite rocks probably have not been thoroughly prospected.

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Project 8312

Reconnaissance Bedrock Geology: Forsyth Lake (East) Area (NTS 74 0-11E)

by D. J. Thomas

The Forsyth Lake area (NTS 74 0-11E) is located north of Lake Athabasca, approximately 85 km east of Uranium City, Saskatchewan. The area averages about 50 percent exposure except in the northeast where it is less than 5 percent. Geological mapping at a scale of 1:50,000 was greatly aided by recent forest fires, affecting about 80 percent of the map area, which provided excellent clean outcrop exposures.

General Geology and Lithological Units

The underlying bedrock of the Forsyth Lake (east) area is predominantly Precambrian quartzofeldspathic gneisses and their migmatitic-granitized equivalents. Lesser amounts of dioritic to quartz dioritic gneisses, metasedimentary rocks and metabasites also occur. Late syn- to post-tectonic granitoids form small plug-like intrusions and sheets. A few isolated post-tectonic lamprophyre and diabase dykes were observed in the extreme southwest.

Dioritic to Quartz Dioritic Gneiss (bd)

Fine- to medium-grained, grey, mesocratic to melanocratic dioritic to quartz dioritic gneiss forms a large semicircular mass south of Forsyth Lake. Biotite and/or hornblende comprise between 20 and 50 percent of the rock. Mafic minerals show marked preferred mineral alignment while gneissic layering is less common and is generally on a millimetre scale. Well-foliated, pink to red pegmatitic and granitic sheets are ubiquitous in this unit.

Quartzofeldspathic Gneiss (fn)

Quartzofeldspathic gneisses are subdivided into felsic biotite (5 to 35 percent) gneiss (fnb) and felsic hornblende-biotite (5 to 35 percent) gneiss (fnh) which underlie up to 60 percent of the area. The rocks are typically fine to medium grained, buff pink to grey with a moderately to well-developed gneissosity. The colour index varies from leucocratic to mesocratic and is locally melanocratic. Mafics typically display a preferred mineral orientation parallel to the gneissic banding. The boundary between felsic biotite gneisses (fnb) and felsic hornblende-biotite gneisses (fnh) is highly subjective due to the centimetre- to metre-scale interlayering of the two types and was selected on the basis of the relative proportion of each within an outcrop area. These quartzofeldspathic gneisses presumably represent the metamorphosed equivalents of immature sediments (i.e. greywackes, arkoses). More mafic varieties may in part be products of argillaceous and/or intermediate volcanic rocks.

Metabasites (mn)

Metabasites form an integral constituent of the quartzofeldspathic gneisses, although few bodies are large enough to be mapped separately. The metabasites occur as boudinaged, concordant to highly discordant layers, ranging from a few centimetres to several tens of metres wide, while strike extensions may be traced for several hundred metres. The most common variety is a 'spotted' amphibolite characterized by millimetre-sized aggregates of white feldspar and/or red-brown garnet. The size and volume of the aggregates is highly variable and gradational within a single amphibolite band, while the 'spots' are commonly elongated and flattened towards the margins of the amphibolite horizon/boudin. The 'spotted' amphibolites are typically concordant to subconcordant to the gross lithological layering of the felsic gneisses and are largely interpreted as metamorphosed mafic flows.

A second, less common form of metabasite comprises foliated, cross-cutting, folded amphibolite sheets which range from less than a metre to several metres wide with strike lengths of several tens of metres. The rocks generally have discrete wall rock contacts, but the general trend and attitude of the bodies tend to be variable. These more uniform and highly discordant amphibolites are considered to be metamorphosed and deformed early diabasic to gabbroic dykes.

Schlieric Granitoid Gneiss (gns)

Two large masses of medium- to coarse-grained, buff pink to grey, weakly foliated to massive schlieric gneisses of

granitic-quartz monzonitic-granodioritic composition outcrop in the southeast and along the northern boundary of the area. Biotite (2 to 10 percent) is generally coarse grained and randomly distributed, and sporadic coarse hornblende (0 to 5 percent) occurs. The schlieren are defined by wispy bands of gneissic felsic material and coarse quartzofeldspathic segregations. The boundary between the schlieric granitoids and quartzofeldspathic gneisses is indefinite where marked by a migmatitic zone ranging from 0.25 to 1.5 km wide. Unmappable smaller bodies of schlieric granitoid gneiss occur along the east arm of Forsyth Lake and around Apisis Lake. The schlieric banding, presence of boudinaged concordant 'spotted' amphibolites and the gradational migmatitic transition suggest that these rocks may be the product of diatexis of the quartzofeldspathic gneisses (fn).

Paragneiss and Undivided Metasediments (n)

Biotite-rich paragneisses and undivided gneissic metasediments form a northwest-trending belt in the southwest and a few isolated discontinuous outcrops in the region underlain predominantly by felsic gneisses. Porphyroblastic, medium-grained, white to rusty-brown, garnetiferous (10 to 40 percent) quartzitic felsic gneisses (na) outcrop in the extreme southwest. They grade rapidly into garnet+sillimanite pelitic biotite gneisses and schists (npb), the more schistose bands of which commonly display a well-developed crenulation cleavage. Pelitic biotite-hornblende gneiss (nph) and migmatitic biotite-hornblende gneiss (nphg) outcrop along the west end of Forsyth Lake and in the area between Sinclair and Bulyea Lakes. The transition between units (nph) and (npg), and the pelitic biotite gneisses (npb) is gradational.

The outcrop of narrow discontinuous layers of migmatitic felsic paragneiss (npg) containing up to 60 percent pelitic paleosome defines larger scale regional fold closures in the area predominantly underlain by felsic gneisses (fn). The pelitic constituents are typically fine to medium grained, gneissic to locally schistose and locally contain several percent almandine garnet and/or sillimanite. Narrow bands of garnetiferous felsic rock, less than 20 m wide and similar to unit (na), are interlayered with migmatitic felsic and pelitic gneisses along the south shore of Forsyth Lake.

The package of paragneisses and undivided metasedimentary rocks is considered to have been derived from interbedded argillaceous, calcareous-argillaceous and arenitic sediments.

Late Granitoids (gl)

Late syn- to post-tectonic 'granitic' (sensu lato) intrusions occur throughout the area. Two distinct types are identified: a coarse-grained, weakly foliated to lineated quartz-rich granite to quartz monzonite (glm) and a massive porphyritic biotite microgranite (glp). The former (glm) occurs as a discordant plug-like mass along Bulyea Lake and as a smaller body at the west end of Forsyth Lake. Porphyritic microgranites (glp) occur as shallow dipping to sub-horizontal sheets less than 30 m thick. Wall rock contacts are typically sharp, although small veins and off-shoots of pegmatitic material are commonly observed along contacts and extending into the country rocks.

Mafic Dykes (d)

In the southwest, a few lamprophyre and diabase dykes generally less than one metre wide were observed crosscutting metasedimentary gneisses (i.e. na, nph, nphg). The lamprophyre dykes trend generally to the northeast, while diabase dykes typically strike more to the north-northwest.

Structure and Metamorphism

Four deformational events are recognized. The first episode (D_1) is marked by a regionally developed gneissosity and associated extensional boudinage, followed by tight to isoclinal folding (D_2) on east-trending axial planes inclined 15 to 30° south. Refolding on northeast-trending axial planes (D_3), inclined about 50° northwest, has produced 'mushroom-style' Type 2 fold interference patterns (Ramsay, 1967). Along the Bulyea River, in the extreme southwest, the D_3 structures appear to be upright and strike north-south.

A widespread penetrative linear fabric (i.e. rodding, crenulation axes) plunging moderately to the west and southwest occurs throughout the area, becoming intensively developed in the southwest. This fabric is considered to be an intersection lineation developed between coaxial D_2 and D_3 planar foliations.

The last deformational event (D_4) is marked by major north, northwest and north-northwest faulting. Faults are generally coincident with well-defined topographic lineaments and are characterized by one or more of the

following: small lithological displacements, brecciation, augen structure, hematization, epidotization and/or chloritization. Drag-folding of lithological units adjacent to these faults is common and was observed up to 100 m away from some structures.

Mineral assemblages in pelitic and felsic paragneisses along the Bulyea River locally include hypersthene and garnet. Axial planar recrystallization of biotite, sillimanite and locally garnet accompanied the D_2 and D_3 deformational events. Quartzofeldspathic lenses as well as larger scale neosomal development accompanied the first three structural events.

Epidote and chlorite occur in rocks immediately adjacent to late faults.

Metamorphic data from the Forsyth Lake area indicates the attainment of granulite facies conditions in the southwest part of the area during the D_1 event. Middle to upper amphibolite facies metamorphic conditions prevailed over the rest of the area during D_1 to D_3, while later retrogression of granulite facies rocks occurred during D_2 as well as along faults during the D_4 event.

Economic Geology

A few minor occurrences of yellow uranium "bloom" were noted on white to buff pegmatites along the Bulyea River. No assessment work has been filed with Saskatchewan Energy and Mines for this map sheet, suggesting that little actual exploration of the Forsyth Lake (east) area has been done.

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Project 8301

Geology and Regional Context of the Oldman Lake Area

by Robert Macdonald

Oldman Lake lies along a lineament which appears to separate rocks of two domains (Fig. 1). In the southern domain, the rocks are wholly supracrustal and vary from garnetiferous quartzofeldspathic to mafic gneisses. Metamorphic grade has attained granulite facies, but the rocks are generally extensively retrogressed. In the domain north of Oldman Lake the rocks are also considered to be largely of supracrustal origin, but they are more uniformly quartzofeldspathic and attained a metamorphic grade of only amphibolite facies. The junction between the two domains along the Oldman Lake lineament is generally marked by extensive cataclasis and sheet granite intrusions. It is proposed to refer to the area of rocks south of the Oldman Lake lineament as the Nevins Lake block and to the northern area as the Train Lake domain.

The terrain south of Oldman Lake is currently well and clearly exposed due to recent widespread bush fires, but north of the lake the rocks are generally encrusted with lichen. The only previous mapping in the area is the reconnaissance 1:250,000 mapping by the Geological Survey of Canada (Baer, 1969). The following text highlights the main features of the rock units; systematic lithological descriptions are given in the legend of the accompanying geological map.

Nevins Lake Block

The rocks in this southern block have been grouped into two major rock units: garnetiferous quartzofeldspathic gneiss (unit F) and pyroxene/hornblende gneiss and granulite (unit Y). Both units show variations, although these are not generally of mappable dimension.

Except in the southwest, most rocks in this block are retrogressively metamorphosed. Attained granulite facies grade is shown by relict hypersthene and pale clinopyroxene. These minerals tend to be better preserved in the coarser mafic bands and in coarse conformable "sweats". Generally, however, mafic minerals comprise only retrogressive hornblende and/or biotite and/or chlorite. Retrogressive effects are displayed in the quartzofeldspathic rocks by prominent pseudomorphing of garnet by biotite, either entirely, commonly producing weathered out rocks, or partially as biotite rims.

The garnetiferous quartzofeldspathic gneisses (Unit F) range from foliated white siliceous gneiss to less uniform varieties interlayered with subquartzite, biotite gneiss (locally rusty), thin metabasite (amphibolite or pyribolite) seams and layers, and calc-silicate pods and layers (subunits Fq, Fm)[1]. The garnet is generally euhedral and varies in amount up to 40 percent of the rock or more. Other minerals present include quartz, plagioclase, K-feldspar, hypersthene, pale clinopyroxene, biotite, chlorite, magnetite and ilmenite. Graphite and sillimanite were observed rarely. Blue-green apatite is a rock forming constituent in some places. Generally the rocks exhibit granoblastic texture.

The pyroxene/hornblende gneiss and granulite (Unit Y), which occurs mainly along the northern part of the domain, is a variable unit, ranging in composition from felsic to mafic, and texturally from homogeneous to strongly compositionally banded. The common denominator in this unit is the presence of hypersthene, clinopyroxene, and particularly hornblende. The hornblende together with biotite mainly appears to be retrogressive after pyroxene. Garnet is generally absent, although intimate interlayering of garnetiferous quartzofeldspathic gneiss occurs locally.

Ultramafic material occurs in narrow lens-like segregations or pods. A uniform medium-grained white-weathering mafic (anorthositic?) variety (subunit Yw) containing little or no quartz is quite abundant. The banded rocks comprise very discrete mafic to felsic layers up to 20 cm wide although usually narrower (Subunit Yb). Thick unboudinaged layers of uniform mafic rock up to about 5 m wide also occur.

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[1]The more uniform varieties correspond approximately to Blake's (1955) "paragneiss" (unit 3), and the interlayered varieties (Fq, Fm) to his "migmatite" (unit 2).

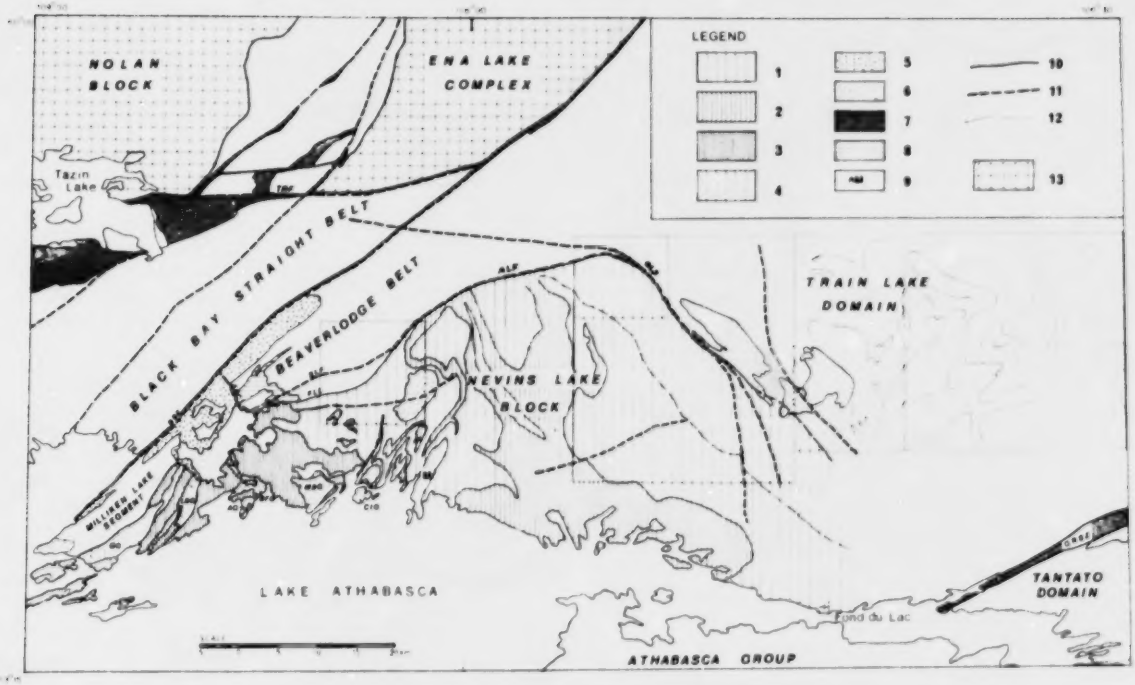

Figure 1 - Sketch map of parts of NTS areas 74 N and 74 O showing main tectonic elements. The terms Nevins Lake Block, Train Lake Domain, Ena Lake Complex and Milliken Lake Segment are new. The Beaverlodge Belt is modified from Beck's Beaverlodge Linear Belt (Beck, 1969). For Nolan Block see Koster (1971) and Bell and Macdonald (1982). For Tantato Domain see Gilboy (1980).

1 to 3, Nevins Lake Block; 1, mainly quartzofeldspathic gneisses, including elements of the Murmac Bay group; 2, mainly high-grade supracrustal rocks (excluding quartzofeldspathic gneisses), probably equivalent to Murmac Bay group; 3, Murmac Bay group, metaquartzite, dolomite, pelite, amphibolite, metavolcanic rocks and iron formation; 4, retrogressively metamorphosed rocks; 5, Martin Group (post-metamorphic); 6, granitoid pluton; 7, mylonitic gneisses, including 'red gneisses' of Koster (1971); 8, Fay Mine supracrustals; 9, large mafic body; 10, approximate domain boundary; 11, major fault or lineament; 12, foliation or lithological trend; 13, other blocks.

CG, Gunnar granite; AG, Athona granite; BFG, Box and Frontier granites; MBG, Macintosh Bay granite; CIG, Cameron Island granite. SLF, St. Louis Fault; BBF, Black Bay Fault; ALF, Alces Lake Fault; OLF, Oldman Lake Fault (and lineament); ABC, ABC Fault; TRF, Tazin River Fault, FLL, Fish Lake lineament; GRSZ, Grease River Shear Zone.

Areas mapped during the 1982 summer are outlined with dotted line.

The Nevins Lake rocks are cut by at least two generations of mafic dyke:

1. Early mafic dykes (unit E), which are cross-cutting but gently folded, foliated and metamorphosed to the granulite facies grade.

2. Young dykes (unit L), post-orogenic and mostly lamprophyre.

Cross cutting irregular pegmatite bodies (unit P) are common in some localities. Some of these, although cross cutting, are clearly of anatectic origin, as they contain minerals such as garnet, as well as showing signs of having attained the regional metamorphic grade.

Train Lake Domain

Rocks in this domain largely comprise pink to pale grey and grey quartzofeldspathic and biotite gneisses which are believed to have derived mainly from psammitic to psammopelitic metasediments. The quartzofeldspathic gneiss (unit Q) is typically biotitic, but hornblende also occurs. Although it is in places remarkably uniform and pink resembling meta-arkose or granitoid, compositional banding is usually present.

Biotite gneiss (unit B) is a grey variant containing more than 5 to 10 percent biotite. As many rocks of this unit are at

or near the stage of anatexis, banding tends to be impersistent and swirly, and quartzofeldspathic sweats and conformable pegmatite are common.

Oldman Lake Lineament

This arc-shaped lineament, which runs through the long axis of Oldman Lake and marks the northern limit of the Nevins Lake block, has a number of associated features:

Mylonitic rocks (units My and Pm, or indicated on the map by code only) occur in a zone up to 1 km or more wide along the lineament. Although pervasive fluxion type protomylonite to flinty mylonite is found along the shore of Oldman Lake, most mylonite occurs in discrete narrow anastomosing bands which in places cut relatively unmylonized rock or mylonitic gneisses of an earlier generation. These late mylonite bands typically range from a few millimetres to several centimetres in width and have a green cherty appearance due to chlorite; texturally they are probably ultramylonite. Areas of anastomosing mylonite are also commonly associated with reddening of the country rock and thin epidotic fractures.

The Oldman Lake lineament is also the main locus of intrusive granitic sheets (unit G), occurring sporadically in a zone several hundred metres wide. Single sheets, which typically comprise medium to fine grained homogeneous weakly foliated pink leucogranite, are mostly less than 100 cm wide.[1] Thicker sheets possibly exist in the marginal zones of the Train Lake domain, but lichen cover makes them difficult to distinguish from massive pink meta-arkosic rocks.

Structure

The presence in places of finely detailed uniform layering, the systematic variation in grain size between lithological layers, the relative paucity of intrafolial folds and boudinage structure, the general absence of mylonitic fabric (apart from in the defined shear zones) and the presence of granoblastic textures all suggest that strain ratios are relatively low in the main domains.

In the small sample of the Train Lake domain represented in the area, the structural patterns appears dominated by upright flat-crested open folds which plunge to the southwest between 20° to 40° (see stereogram on accompanying map). Mineral lineation, rodding and rare minor folds plunge coincidently with the regional fold plunge.

In the Nevins Lake block the structural pattern indicated by the small statistical sample, both in outcrop pattern and structural analysis, is less simple. The Train Lake regional fold pattern shows up in a synoptic stereogram for banding foliation of the whole domain, but the girdle of foliation poles is much more diffuse, indicating considerable variation in regional plunge from 70° to 30° south, and there are also northerly plunges. The direction of fold plunge displayed by the foliation pole girdle varies from southwesterly to southeasterly. The style of folding appears as steep limbs (trending north-south to north-northeasterly) with flat crests, almost like box folds. The fold geometry in total is probably due to interference folding varying from northerly-verging overturned folds and upright folds on northerly-trending axes (Ramsay Type 2 interference) with doubly-plunging fold geometry (Ramsay Type 1). Part of this fold interference may be ascribable to superimposition of the Train Lake structures.

Cross-cutting pegmatites (unit P) in the northwestern part of the Nevins Lake block trend fairly consistently east-west (20 observations). The young dykes (mainly lamprophyre) trend northeasterly for the most part (14 observations). Mafic dykes were not observed in the Train Lake rocks.

The Oldman Lake lineament marks a fairly abrupt structural transition between the Nevins Lake block and the Train Lake rocks. At the map scale the lineament clearly truncates rock units of the southern block, although less noticeably so to the south east. Apparent early mylonitic to augen foliation surfaces generally dip at moderate to steep angles to the southwest in a pattern broadly similar to foliation in the Train Lake rocks. Late anastomosing ultramylonitic veins repeat this pattern, but include also oblique zones and steeper dips indicative of conjugate shear patterns. Some of the last-mentioned are reflected in valley lineaments, conspicuous also by the presence of reddened rock; they probably also grade into late brittle faults or master joints, although little evidence for this was seen.

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[1] The intensively reddened mylonitic zones, together with the pink granite sheets and epidotic fractures are reminiscent of Kosters (1971) "red gneiss" descriptions.

The major late fault along Oldman Lake splays at the western end, one arm passing southwestwards through Alces Lake to connect with the St. Louis Fault, the other passing westwards towards Stretching Lakes.

The pink intrusive granite sheets (unit G) associated with the Oldman Lake lineament, crosscut foliation, dipping generally at a shallower angle to the south and west, following the trend of the lineament. Late anastomosing mylonite and minor faulting commonly crosscut these sheets, but in places the sheets are later than the mylonite, suggesting that the granite was intruded broadly in association with tectonism along the lineament.

Tectonic Interpretation

Baer (1968), who produced the only previously existing map covering this terrain, identified the rocks lying south of Oldman Lake as a retrogressed polymetamorphic terrain of attained granulite facies grade, and those north of the Lake as a single cycle amphibolite facies terrain. He proposed that the southern and northern terrains were respectively composed of Archean and Aphebian rocks.

Harper (this volume), describing the area immediately south of the present area, suggests that an amphibolite facies metamorphism occurred in the Nevins Lake rocks which may equate with the amphibolite facies event in the northern terrain and that the granulite facies metamorphism in the Nevins Lake block is younger.

Thomas, D.J. (this volume, pers. comm.), working further south along the Oldman lineament where its effects are less pronounced, finds that it is difficult to recognize a fundamental lithological and structural distinction between rocks of the two domains, and considers they and the tectonic events which affect them may be broadly coeval.

The three tentative viewpoints raise the issue of whether the Nevins Lake block is distinct from the Train Lake domain because it is part of an older (cratonic) mass, or whether rocks of the two domains are broadly coeval stratigaphically but distinctive because they reflect exposure of different crustal levels and/or different lateral parts of a broad orogenic assemblage.

In contribution to this issue it is noted in respect of the Oldman Lake area that:

1) Structural trends in the Nevins Lake block are truncated at the Oldman Lake lineament. Similar truncation appears to exist further west along the Oldman lineament at Alces Lake (Blake, 1955).

2) Retrogressive metamorphism in the Nevins Lake block is regional in extent and mostly non-dynamic, involving little 'reworking' of the rocks (except in defined shear zones and discrete refoliation zones). Many of the rocks contain pervasive chlorite as well as biotite. Chlorite, epidote and altered feldspar are abundant in the proximity of shear zones. Further study would be required to determine to what extent retrogression in the block is due to the amphibolite facies metamorphism of the Train Lake domain, or to what extent it is due to the cataclastic events associated with the Oldman Lake lineament.

Mineralization

Radioactive hot spots occur close to the Oldman Lake lineament; some were detected measuring up to 50 times background count. These mainly appear to be associated with fractures in pegmatite.

Appendix: Definition of Domains

The Nevins Lake block includes the terrain extending as far west as Beaverlodge Lake and bounded to the north by the cataclastic lineament extending northwestwards from Bulyea Lake through Oldman, Alces and Prince Lake to Eldorado. The domain possibly comprises one major stratigraphic unit (supergroup?), including the Murmac Bay Group and similar supracrustal rocks which can be identified as far east as the section east of Nevins Lake, and a preponderance of various quartzofeldspathic units many of which are represented in the Oldman Lake area. Attained metamorphic grade increases to granulite facies to the north and east, but a wide zone along the eastern margin is regionally retrogressed. Discrete granitic plutons mainly occur along the Lake Athabasca shoreline. The structural style varies throughout the domain, and includes areas of complex interference folding. Further discussion on this domain is found in Thomas and Macdonald (this vol.).

The Train Lake domain lies east and northeast of the Nevins Lake block, comprising mainly quartzofeldspathic supracrustal gneisses in places highly anatectic and migmatic, and intruded by larger granitic sheeted bodies.

By existing accounts these rocks attained amphibolite facies grade during only one orogenic cycle.

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Project 8307

Review Geology: Prince Lake Area (Part of NTS 74N-9)

by M. W. Thomas and Robert Macdonald

Prince Lake is situated approximately 20 km east of Uranium City and lies on the lineament connecting the St. Louis fault northeastward through Alces and Oldman Lakes. The area around Prince Lake was mapped regionally by the Geological Survey of Canada at 1:63,360 scale (Christie, 1953; Blake, 1955). The western portion abuts against the Beaverlodge mining area mapped at 1:14,400 scale by Tremblay (1972). This summer about 20 days were spent in an attempt to establish some tectonic identity for the area around Prince Lake, as part of the Project Beaverlodge regional review. The accompanying geological map provides traverse details and lithological information gathered during these field examinations.

Apart from sporadic pelite, amphibolite and metaquartzite, most rocks of the Prince Lake area are quartzofeldspathic in composition. However, they can be areally divided into three tectonic regions (see geological map):

1) Nevins Lake Block (Macdonald, this volume)
outcropping south and east of the St. Louis fault and believed to comprise Murmac Bay group supracrustal rocks and quartzofeldspathic equivalents, intruded by granitoid plutonic rocks.

2) St. Louis Cataclastic Belt
lying within and adjacent to the St. Louis fault.

3) Foot Bay Gneiss and rocks of the Zenith Lake Structure
comprising quartzofeldspathic gneisses outcropping northwest of Prince Lake.

Post-orogenic lamprophyre dykes cut the Foot Bay Gneiss and rocks of the Nevins Lake block. Although not observed in the Prince Lake area, basic dykes also crosscut most cataclastic rocks (Tremblay, 1972; Sassano et al., 1974).

Nevins Lake Block

In the southeast part of the map area diverse supracrustal rocks occur, including metaquartzite, amphibolite, pelite and interlayered rocks (units Q, M, P and X respectively). They are identical to rocks mapped north of Mackintosh Bay (Macdonald et al., 1982) and are considered to correlate with the Murmac Bay group. Further north towards Forget Lake, layers of metaquartzite, calc-silicate rock and amphibolite occur amongst predominantly white banded quartzofeldspathic gneisses (unit W). The supracrustal rocks are intruded by a distinctively megacrystic granodiorite (unit MG) centred around Hutton Lake.

Metaquartzite, amphibolite, pelite and banded quartzofeldspathic rocks also occur in the southwest around Billo and Max Lakes. They are here associated with a uniform pink granite (unit G).

Regional metamorphic grade increases in a northeasterly direction from amphibolite to granulite facies. Sillimanite is recorded in the southeast and hypersthene-bearing gneisses occur north of Hutton Lake. The northeasterly increase in grade manifests itself across the megacrystic granitoid at Hutton Lake, which is waxy and hypersthene-bearing in the north and hornblende + biotite-bearing in the south. In the supracrustal rocks, a general coarsening in grain size accompanies this rise in grade.

Folds in the supracrustal rocks generally exhibit moderate south-southwesterly plunging axes and steeply dipping axial surfaces, as exemplified by the synform west of Gale Lake. A comparable fold pattern was mapped in the Murmac Bay group to the south (Sibbald, 1982; Macdonald et al., 1982) and is also reflected by folded gneissosity in the megacrystic granodiorite (unit MG).

The pink granite (unit G) south of Billo Lake displays a northwest trending foliation which is strongly oblique to the regional structure in this part of the Nevins Lake block. Tremblay (1972) has mapped northwest trending folds in this area and also further west towards Eldorado. These northwesterly structures have been interpreted either as relict (Kenoran?) trends indicative of Archean basement (Morton and Sassano, 1972) or, in the Mickey Lake - Ace Lake area to the northwest, as late structures post-dating northeasterly trending folds (Thomas, 1981, 1982).

St. Louis Cataclastic Belt

This northeasterly trending belt is over 2 km wide on the west edge of the map area but thins rapidly to 0.5 km in width north of Prince Lake. For the most part the belt contains quartzofeldspathic cataclastic rocks with sporadic sheared layers of metaquartzite, chloritic schist and amphibolite (units Y, Qb, Mc and Ma). Well developed fluxion structure, red to pink feldspar porphyroclasts and pervasive chlorite are characteristic. Ultramylonites, and other products of extreme cataclasis seem to be concentrated along Prince Lake (the trace of the St. Louis fault) and also in a southwesterly trending belt east of Viking Lake. In these zones, mylonite commonly occurs in narrow anastomosing bands around enclaves of earlier mylonitic gneiss and/or relatively unsheared rock. Late brittle faulting, crush breccias and open druse fractures were also noted in these zones.

A distinctive vermiform textured granitoid (unit VG) is a common but minor constituent in the belt and also occurs along east-northeasterly trending lineaments splaying off the St. Louis fault. This granite is composed of coarse salmon pink feldspar and vermiform aggregates of white quartz, and is locally sheared. Enclaves of blue-quartz granitoid (unit BG) indicative of retrogressed granulite facies rocks were also locally identified.

Retrograde metamorphism and alteration are intimately associated with the shearing along the St. Louis cataclastic belt. Chlorite, epidote, calcite, specularite and vein quartz are common. The varying alteration effects are well documented by Tremblay (1972).

The orientation of mylonitic foliation and fluxion surfaces is quite variable within the cataclastic belt and folded mylonites are common. As proposed by previous workers in the Beaverlodge area, numerous generations of cataclasis likely took place along this zone.

The effects of pervasive shearing and retrogression rapidly die out laterally away from the cataclastic belt but discrete shear/alteration zones commonly exhibiting fluxion, chloritic-epidotic alteration and/or reddening of feldspars occur throughout the Prince Lake area. East of Viking Lake, red quartzofeldspathic gneiss (unit R) appears to represent a retrograde transition zone between the cataclastic belt and quartzofeldspathic gneisses of the Nevins Lake block. On one traverse, chloritized parts of unit R and hypersthene-bearing quartzofeldspathic gneiss (unit W) were seen to be interleaved over 200 m. The contact between these two units is thus interpreted to be metamorphic rather than stratigraphic.

Foot Bay Gneiss and rocks of the Zenith Lake Structure

Immediately northwest of Prince Lake are pink to dark red, hornblendic and biotitic quartzofeldspathic gneisses (unit F) which are similar and contiguous with outcrops of the Foot Bay Gneiss as described by Tremblay (1972). The gneisses are typically medium to fine grained and slight compositional differences have produced a uniform banding at all scales. Other than containing sporadic layers of metaquartzite, as well as amphibolitic and garnetiferous rocks, the Foot Bay Gneiss is lithologically monotonous.

In the Zenith Lake structure, a large antiformal fold mapped by Blake (1955) north of Prince Lake, quartzofeldspathic gneisses are generally pink to grey and contain abundant semi-conformable magnetite-bearing granite pegmatites (unit Z). Otherwise, they are very similar to the Foot Bay Gneiss. Regional metamorphism in both these units reached at least garnet grade in the amphibolite facies. Local chloritic alteration of mafic minerals and the characteristic presence of epidotic fractures is presumably related to shearing and retrogression effects from the St. Louis cataclastic belt.

The Foot Bay Gneiss and rocks of the Zenith Lake structure have been distinguished on the geological map solely by their contrasting structural styles. Preliminary analysis of gneissosity and banding orientations in the Foot Bay Gneiss has produced an apparently isotropic pattern on the stereogram. It appears likely that complex fold interference structures occur in this unit and are obscuring the resulting structural pattern. In sharp contrast, banding and gneissosity surfaces in rocks of the Zenith Lake structure outline a large, northeast-southwest trending, moderate southerly plunging antiform. This attitude is subparallel to the predominant fold direction in the Nevins Lake block described previously and also conforms in attitude to the Donaldson Lake antiform to the southwest (Tremblay, 1972; Thomas, 1981). The southeastern limb of the Zenith Lake structure is sheared out along the St. Louis cataclastic belt and in this area shearing and retrogression have produced red gneisses very similar to unit R. The contrasting structural signatures of the Foot Bay Gneiss and the Zenith Lake structure are conspicuous

on 1:60,000 scale aerial photographs of the area.

Discussion

1) Supracrustal Rocks of the Nevins Lake Block

It has been noted that a gradual increase in quartzofeldspathic component occurs in the Murmac bay group supracrustal rocks from the type area around Beaverlodge Lake eastward to Mackintosh Bay (Macdonald et al., 1982). This year's investigations in the Prince Lake area show a similar variation; interlayered, compositionally diverse rocks outcrop in the south part of the area whereas banded quartzofeldspathic gneisses (unit W) with only sporadic layers of Murmac Bay-type lithologies (metaquartzite, amphibolite, calc-silicate rock) occur toward the north. It appears likely, therefore, that these quartzofeldspathic gneisses are Murmac Bay group equivalents. This contention is supported by the gradual variation in metamorphic grade, the coherence of structural styles and the similarity of plutonic histories which have been described in this part of the Nevins Lake block. The progressive increase in abundance of quartzofeldspathic rocks to the northeast is likely due either to a sedimentary facies variation or to exposure of a different stratigraphic level within the supracrustal package.

2) Quartzofeldspathic Rocks of the St. Louis Cataclastic Belt

In the Beaverlodge map area to the west, Tremblay (1972) included the generally sheared quartzofeldspathic rocks of this belt with his unit 19, metasomatic granite. The mylonitized metaquartzites, chloritic schists and amphibolites, however, are almost assuredly derived from the Murmac Bay group. This relationship has been advocated by Morton and Sassano (1972), is implied by Tremblay (1972) and is supported by this summer's field work. If this is true it seems likely that the quartzofeldspathic cataclastic rocks are also derived from Murmac Bay group equivalents which are largely quartzofeldspathic in this area. The association of blue quartz granitoid with the cataclastic rocks supports this argument; the only proximal granulite facies terrain so far identified from which blue quartz could be derived is in the Nevins Lake block several kilometres to the east.

3) Age relationships

Radiometric age dating in the Beaverlodge and adjacent areas has provided some time constraints applicable to rocks in the Prince Lake area. The Foot Bay Gneiss has yielded a U/Pb zircon age of 2513 Ma (Tremblay et al., 1981). The Murmac Bay group is intruded by granite plutons which have yielded preliminary Rb/Sr ages in the range 2100-2200 Ma (Bell and Blenkinsop, 1982). Also, basic dykes which postdate the 'major catalastic deformation' in the vicinity of the St. Louis fault have been dated at c. 1800 Ma (Sassano et al., 1974).

In spite of these dates, the age relationships of the rocks in the area are far from clear. Tremblay (1972) initially proposed that all crystalline rocks in the Beaverlodge area are late Archean in age but later (Tremblay et al., 1981) did not exclude the possibility advanced by Morton and Sassano (1972) from structural evidence that the Foot Bay Gneiss is Archean basement to early Aphebian supracrustal rocks (including the Donaldson Lake Gneiss, Fay Mine complex and Murmac Bay group). Tremblay et al. (1981) also raised the possibility that the Foot Bay Gneiss date of 2513 Ma may be a precursor age as it was produced from zoned zircons of presumed igneous parentage. In this case, the Foot Bay Gneiss could be early Aphebian as well.

This summer's work has revealed little further information concerning the relative ages of the Foot Bay Gneiss, Murmac Bay group and rocks of the Zenith Lake structure. However, the apparently unique structural signature of the Foot Bay Gneiss northwest of Prince Lake seems to support the argument that the unit represents an older basement terrain.

Conclusions

1) Murmac Bay group equivalents outcrop as far north as Forget Lake where they are predominantly quartzofeldspathic gneisses. This compositional variation from the type area around Beaverlodge Lake may result from either a facies change, or exposure of a different stratigraphic level within the supracrustal package.

2) Prograde regional metamorphism in the Nevins Lake block increases toward the northeast with attainment of granulite facies north of Hutton Lake.

3) Rocks in the St. Louis cataclastic belt, including many if not most quartzofeldspathic types, are considered to be mainly derived from the Murmac Bay group and equivalents in the Nevins Lake block.

4) Foot Bay Gneiss differs markedly in structural signature from all other rocks examined in the area. The structure does not appear to reflect either a northwest trend suggested by Morton and Sassano (1972) to be a relict Archean (Kenoran?) direction characteristic of Foot Bay Gneiss, or the northeast trend prevalent in the Donaldson Lake antiform (Tremblay, 1972), the Zenith Lake structure, and folds of the Nevins Lake block.

5) The relative ages of the Murmac Bay group, Foot Bay Gneiss and rocks of the Zenith Lake structure are not certain. The apparently unique structural signature of the Foot Bay Gneiss northwest of Prince Lake appears to support the contention that it is older basement. More detailed structural and radiometric dating studies will likely be required in order to settle this issue.

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Project 8306

Sub-Athabasca Basement Geology Project

by C. F. Gilboy

During the past summer, core from 421 drillholes stored at 28 different locations[1] was examined and sub-Athabasca basement sections were summarily logged. This brings to 1,651 the total number of drill cores inspected during the course of the project, the fieldwork side of which is now essentially complete. Periodic updating will be carried out whenever necessary.

The source of most of the recently studied material lies beneath the northern and eastern parts of the Athabasca Basin. These areas had previously received relatively little attention by this project. Unfortunately, from the point of view of interpreting the geology below the Athabasca Group sediments, very little relevant work has been carried out in the central portion of the basin. Conductors have only been reliably detected through less than 500 to 600 m of Athabasca Group rocks plus Quaternary overburden. This limits active exploration for unconformity-type uranium deposits to a 15 to 30 km wide band immediately inside the edge of the Athabasca Basin, except in the southeast where the band expands in width to about 60 km.

Methods of Investigation

The main sources of information for compiling geological maps of basement rocks situated under the Athabasca Group were described in last year's Summary of Investigations (Gilboy, 1982). They include both direct (core examination) and indirect (interpretation of geophysical data) techniques. The usefulness of core is limited by the regionally sparse distribution of drillholes and by the very selective location of the latter over specific exploration targets. In attempting to understand the general geology of the sub-Athabasca basement, therefore, a heavy bias has necessarily been placed on interpreting the results of various types of electromagnetic and magnetic surveys.

Geochemical and radiometric surveys have also been much used as exploration tools in the Athabasca Basin, but their results are of little help in obtaining information about the rock types that make up the sub-Athabasca basement. However, a total of 78 unaltered core samples, generally of quartzofeldspathic composition, were collected for analysis of their major oxides and selected trace elements. The results will be processed with a view to distinguishing geochemically between visually 'typical' meta-arkoses (Aphebian) and felsic gneisses (probably Archean). If the geochemical signatures of these two rock types prove to be characteristic, they will be useful in distinguishing coarsely recrystallized representatives of the meta-arkoses from the felsic gneisses.

Geology

Preliminary 1:250,000 scale geological maps of the Lloyd Lake (NTS Sheet 74F) and Pasfield Lake (NTS Sheet 74I) areas accompany this account. Both areas present serious problems in reliably interpreting their sub-Athabasca basement geology. The Lloyd Lake region is structurally and lithologically complex, and the western part of the Pasfield Lake region has been little explored to basement.

Lloyd Lake Area

Lewry and Sibbald (1977) proposed that three distinct lithostructural domains are recognizable in the southwestern part of Saskatchewan's Precambrian Shield. From west to east, these are the Firebag Domain, the Clearwater Domain and the Western Granulite Domain.

Rocks of the Firebag Domain do not crop out in Saskatchewan, but are reportedly exposed in Alberta, where they appear to be part of a

[1] Waterbury Lake, Close Lake, Pasfield Lake, Kernaghan Lake, Richardson Lake, Umfreville Lake, Prime Island, Eileen Lake, Newnham Lake, Fife Island, Deadcree Point, Helmer Lake, Maurice Bay, Uranium City (two locations), Pine Channel (two locations), Stony Rapids, Keefe Lake, Russell Lake, Williams Lake, Binkley Bay, Phoenix Lake, Umpherville Lake, Dufferin Lake, Patterson Lake, Eastley Lake and Carswell Lake.

retrogressed granulite terrain (Tremblay, 1961; Lewry and Sibbald, 1977). The high aeromagnetic relief in this domain has a pronounced curvilinear pattern, thus resembling the Western Granulite Domain to the east.

Core from twelve drillholes in the Firebag Domain appears to be made up of metamorphosed supracrustal rocks that were strongly retrogresssed after reaching their highest metamorphic grade. Garnet crystals are largely pseudomorphed by hematite and chlorite, and biotite by chlorite. Intense deformation accompanied the retrogression, and submylonitic fabrics are readily distinguished in core from six of the twelve drillholes. Graphite seems to be a rare accessory mineral in these supracrustals, and was tentatively identified in only two cores.

The Clearwater Domain is characterized by lower aeromagnetic and gravity values than the adjacent domains (Wallis, 1970; Lewry and Sibbald, 1977) and, dramatically, by flat aeromagnetic relief. Rocks of the domain are exposed only in the Clearwater River gorge, 90 km due south of the southern edge of the Athabasca Basin. There, three rock types are represented: equigranular granite, megacrystic granite and felsic gneisses. The granites compare closely with the Junction Granite that bounds the Western Granulite Domain along its southeastern edge. The felsic gneisses appear similar to those of the Virgin River and Mudjatik Domains, and thus differ markedly from the blue quartz gneisses of the Western Granulite Domain (Lewry and Sibbald, 1977).

Twenty-one cores have been studied from drillholes that penetrate rocks of the northern extension of the Clearwater Domain. As in the Firebag Domain, all are composed essentially of metamorphosed supracrustal rocks that range in type from pelites to psammites and quartzites. Quartzite is present in the majority of cores. Graphite is rare, and was observed in small amounts in only five cores. The absence of felsic gneisses and granitoid rocks from this part of the sub-Athabasca portion of the Clearwater Domain may simply reflect the selective siting of the drillholes over exploration targets.

The Western Granulite Domain occupies the eastern part of the Lloyd Lake area. Rocks of the domain are well exposed to the south of the Athabasca Basin, where they have been mapped by Scott (1977), who found granulite facies rocks to be dominant. These are interbanded conformably with mixed paragneisses which are commonly graphite-sillimanite-garnet-biotite pelites and semipelites, but which also contain psammites, quartzites, amphibolites and siliceous iron formation. Granite bodies up to about 1 km in width lie parallel to the regional northeasterly structural trend of the host rock. The characteristic high aeromagnetic relief of the domain is prominent on the regional aeromagnetic maps of the Lloyd Lake area.

More than 60 cores which intersect Western Granulite Domain rocks have been summarily logged. They essentially conform to the findings reported by Scott (1977), except that metasediments are dominant. This is again viewed as the result of biased drilling rather than of any fundamental change in the geology. Only six cores contain microscopically confirmed hypersthene-bearing rocks, most of which are charnoenderbitic to enderbitic. One of these cores contains graphitic semipelite with pinite-sericite pseudomorphs probably derived from cordierite, interbanded with rock that compositionally approaches anorthosite. In relation to core from the two more westerly domains, quartzite is a rare rock type, and graphite an abundant accessory mineral. Garnet is almost ubiquitous, but is commonly severely retrogressed to biotite, chlorite, carbonate and/or opaque minerals. Biotite and plagioclase, too, are typically partially or totally retrogressed - the former to chlorite, the latter to sericite or chlorite. Thin-section studies show that quartz typically displays extreme undulose extinction along with an incipient breakdown in grain size; also, quartz encloses tiny needles of sillimanite wherever the host rock is, or was, sillimanite-bearing. Blue quartz is present in several drill cores from this domain. Granitoid rocks are common as injections or segregations within other rock types. As granitoid rocks form the sole rock-type penetrated in only six drillholes, no mappable granite plutons were identified.

Diabase occurs in the extreme east near Sand Hill Lake, where it forms an east-west dyke, emplaced into Athabasca Group sandstones and into sub-Athabasca basement, which penetrates Western Granulite Domain basement rocks. Diabase also probably causes a NW-SE linear aeromagnetic anomaly that crosses the northern edge of the map-area near Dayman Lake. This latter interpreted dyke is situated in the Clearwater Domain.

To summarize the sub-Athabasca geology of the Lloyd Lake area, the subdivision into three lithostructural domains proposed by Lewry and Sibbald (1977) based mainly on the aeromagnetic signatures of the constituent

rocks is broadly upheld. In the west, supracrustal rocks of the Firebag Domain are extensively mylonitized; in the Clearwater Domain quartzites are a widespread constituent in the metasediments; graphite is rare in both regions. However, evidence is meagre that the Clearwater Domain is a zone of more extensive Hudsonian mobility than the Firebag or Western Granulite Domains, as rock types encountered in core differ completely from those that crop out in the same domain along the Clearwater River. It is readily apparent that core from the Western Granulite Domain is made up of the same rock units which crop out farther south, as the core mainly comprises retrogressed graphite-garnet-biotite-sillimanite pelites and semipelites which have been through a metamorphism that peaked in granulite facies conditions. Waxy greenish-grey enderbites and charnoenderbites of unknown parentage are interbanded with metasediments.

Pasfield Lake Area

The Pasfield Lake Area contains sub-Athabasca basement that mostly lies in the Mudjatik/Virgin River Domains. Rocks and elongated dome-and-basin structural patterns characteristic of the Wollaston Domain are restricted to the southeastern corner of the map sheet area. The Mudjatik and Virgin River Domains, both readily distinguishable to the south of the Athabasca Basin, have not been recognized as separate geological entities east of Stony Rapids, northeast of the Basin, where mapped areas have all been assigned to the Mudjatik Domain (Gilboy, 1978, 1979; Lewry 1979; Ray 1978). The extrapolated connection between the Black Lake Shear Zone in the north and the Virgin River Shear Zone in the south passes almost directly through the northwestern corner of the Pasfield Lake area. Only one drillhole has penetrated identifiable basement close to this point; it intersected 50 m of dense mafic biotite-amphibole gneisses, possibly metamorphosed basic to intermediate volcanic rocks, cut by carbonate veins up to about 1 cm thick. Other drillholes sunk in the thickly sandstone-covered western part of the area between Poitras and Pasfield Lakes encountered foliated granitic rocks. In the north, close to Umfreville and Orr Lakes, uniform pale pink medium-grained amphibole-biotite and biotite felsic gneisses are dominant. They are locally interbanded with amphibolitic layers 1 to 5 cm thick.

Most drilling and other exploration activity has been concentrated into a region southeast of Cushing, Unknown and Durrant Lakes; it has resulted in the discovery of important uranium deposits at Waterbury and Midwest Lakes. In this southeastern region, most drilled E/M conductor targets are underlain by graphitic pelites and semipelites of the Wollaston Group. Sillimanite is recognizable in many of the metasediments encountered in drilling in the Mudjatik Domain; it is in places extensively altered to muscovite, which forms late, large, randomly oriented crystals. Sillimanite is far less common in the Wollaston Domain metasedimentary core. Calc-silicate rocks are present but rare, and are intimately associated with pelites and semipelites. Wollaston Group meta-arkose is also encountered only very rarely. Homogeneous felsic gneisses in the southeastern region have been intersected close to La Rocque and Midwest Lakes. Felsic gneisses that are texturally and/or compositionally inhomogeneous, and that may therefore be derived from suites of supracrustal rocks, occur in the vicinity of Kernaghan Lake and east of Waterbury Lake.

Diabase has been intersected only rarely by drilling in the Pasfield Lake area (e.g. about 1 km south of Midwest Lake). However a 60 km long southeast-northwest trending linear aeromagnetic anomaly that stretches from Durrant Lake to the northern edge of the area several kilometres east of Umfreville Lake is considered to be caused by a diabase dyke.

To summarize the sub-Athabasca geology of the Pasfield Lake area, most of the northwestern and central parts appear to be underlain by generally uniform pink felsic gneisses of probable Archean age, although mafic biotite-amphibole gneisses in the extreme northwest may represent younger (Aphebian) metavolcanic rocks such as those found immediately east of the Black Lake Shear Zone in the Black Lake and Charlebois Lake regions farther north (Gilboy, 1978). Aeromagnetically, these rocks have flat relief and the thick sedimentary cover apparently masks well-defined trends; overall, the aeromagnetic values are moderately high.

In the southeast, more geological and geophysical variation exists. A mixed suite of Aphebian metasediments is widely developed, mainly representing near-basal sequences of the Wollaston Group characterized by graphitic pelites and semipelites. The rocks nowhere show evidence of metamorphic grades higher than upper amphibolite facies; they have been locally subjected to a late, low-grade static metamorphism that partially destroyed sillimanite, converting it into randomly oriented muscovite flakes. Folds are distinguishable only in the southeast; their

pattern is characteristic of the Wollaston Domain in which deformation is mostly related to the Hudsonian orogeny. Accompanying igneous activity is essentially limited to the injection of granitic to pegmatitic minor intrusives; the pegmatites are commonly tourmaline-bearing where they inject Wollaston Group metasediments. A much later period of igneous activity (Helikian in age) was responsible for the emplacement of diabase dykes into sub-Athabasca basement rocks and Athabasca Group sediments.

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Project 8307

Compilation Bedrock Geology Series: Progress Report

by M. W. Thomas

In 1974, the Saskatchewan Geological Survey initiated production of a series of 1:250,000 scale compilation bedrock geological maps covering the Precambrian Shield in northern Saskatchewan. At that time, detailed and up-to-date geological information was not available for large areas of the north and a start was therefore made on compiling the better known areas. This involved both office compilation and field checking. The first preliminary report on the Pelican Narrows (NTS 63M) and Amisk Lake (NTS 63L) areas appeared in the 1975 Summary of Investigations. Since then, with much of the previously unmapped terrain covered by the Saskatchewan Geological Survey at 1:100,000 reconnaissance scale, numerous monochrome preliminary compilation maps have been produced in the annual Summary (Fig. 1).

During the past year, a standard production format for publication of the compilation series in full colour has been finalized and four maps, namely NTS 64E Reindeer Lake North, NTS 64L Wollaston Lake, NTS 74A Foster Lake, and NTS 74H Geikie River have been recently published by the department. These maps include geological annotations and information on the sources of compilation. Comprehensive bibliographies for each of these four areas have also been compiled and are on open file.

Depending on future available resources, it is hoped that up to six more final coloured maps and one more preliminary (monochrome) map will be released during 1984 (NTS sheets 63L/63K, 63M/63N, 74B, 74F, 74G and 74P).

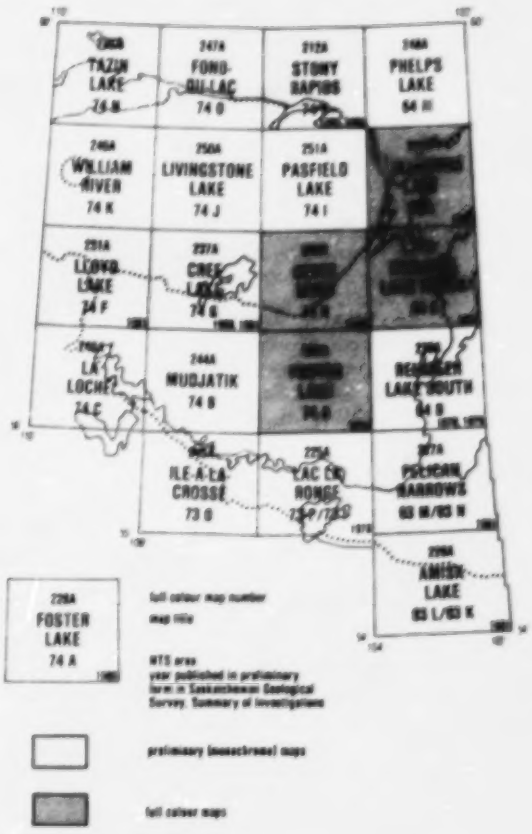

Figure 1 - Index to maps of the Compilation Bedrock Geology Series.

Saskatchewan Shield Geochronology Project (Rb-Sr Method)

by Keith Bell[1] and John Blenkinsop[1]

During 1982 efforts were concentrated on establishing the whole-rock Rb-Sr geochronology of granitoid rocks from the Uranium City area. Samples were collected from the Box, Cameron Island, Lodge and MacIntosh Bay bodies. A suite was also obtained from a single volcanic unit of the Martin Formation at the south end of Martin Lake. Additional samples from the Sahli granite that lies in the Hanson Lake Block were also analyzed.

Almost all of the isotopic data from the samples indicate some degree of open-system behaviour, yielding scatterchrons rather than true isochrons. This is particularly true of the data from the Martin volcanics. The data show a pronounced scatter and do not even approximate a straight line on the isochron diagram in spite of the fact that these samples were carefully collected from a single unit and were some of the freshest material available.

Samples from the MacIntosh Bay body give data that approximate an isochron, corresponding to an age of 2000±30 Ma and an initial ratio of 0.731±0.002. The Cameron Island granite gives a tentative age of 1865±120 Ma. The scatter exhibited by most of the data from other granitoid rocks in the Uranium City area is likely related to their fairly low Sr (20 to 80 ppm) contents. Although we do not yet know the exact age of the other igneous bodies, the initial $^{87}Sr/^{86}Sr$ ratios cannot be lower than 0.740, suggesting that these bodies contain a significant component of crustal material. In general, their overall geochemistry is quite unlike any of the other bodies we have analyzed from the Saskatchewan Shield.

A date of 2410±40 Ma previously obtained by us from the high-grade (granulite facies) Shali granite was interpreted as a metamorphic age, a feature consistent with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7056±0.0005. Additional analyses from this body did not change the estimate of the age but significantly increased the scatter. This event, however, still remains one of the oldest reflected by the whole-rock Rb-Sr method in the Saskatchewan Shield.

All errors have been quoted at the 2 sigma level.
$^{87}Rb = 1.42 \times 10^{-11} y^{-1}$

[1]Department of Geology, Carleton University, Ottawa. Project supported by Saskatchewan Energy and Mines.

Project 8304

Zircon Isotope Geochronology Project: U-Pb (Zircon) Chronology for the Hudsonian Orogenic Terrains in Saskatchewan

by M. E. Bickford[1], John F. Lewry[2] and W. R. Van Schmus[1]

A program of U-Pb zircon age determinations has been designed to date major igneous events in the Hudsonian orogenic terrains of Saskatchewan (and parts of Manitoba) and is currently being implemented. The program is a collaboration between the writers and the Saskatchewan Geological Survey, and is being supported by the U.S. National Science Foundation (grant to Van Schmus and Bickford), by NSERC (grant to Lewry) and by Saskatchewan Energy and Mines. The first 24 samples were collected during late June and early July, 1983. As funding becomes available, further field collection and laboratory work are planned over a three-year period beginning in January, 1984. Close collaboration is planned with Rb-Sr studies of the Saskatchewan Shield Geochronological Project (see Bell and Blenkinsop, this volume).

Knowledge of the Trans-Hudson Orogen in Saskatchewan was greatly advanced by extensive Saskatchewan Geological Survey field mapping and related studies during the 1970s. On the basis of this work, geotectonic models have been developed which suggest the presence, within the orogen, of such tectonic features as accreted volcano-plutonic arcs, fore-arc basinal deposits, collisional sutures, possible Archean microcontinents and variably remobilized Archean continental lithosphere (Lewry, 1981a, 1981b; Lewry and Sibbald, 1980; Lewry et al., 1978, 1981, in press; Ray and Wanless, 1980).

For example, the MacLean (metasedimentary) Belt or Domain (Fig. 1) is believed to represent a telescoped fore-arc basin (Lewry, 1981a). Migmatized metagreywacke turbidites, metavolcanic rocks and arkoses of the Kisseynew Domain interdigitate with supracrustal rocks of the Flin Flon - Snow Lake volcano-plutonic arc to the south and with similar rocks of the La Ronge - Lynn Lake arc to the north, suggesting that the Kisseynew rocks developed at least in part contemporaneously with arc development. The Glennie Lake Domain and Hanson Lake Block may contain Archean or early Proterozoic microcontinental elements, although Archean rocks are as yet unconfirmed by radiometric data. The Glennie Lake Domain has a distinctive lithostructural style and is bounded largely by major tectonic discontinuities (the Tabbernor Zone and the Stanley Shear Zone). Volcanic and granulite facies granitoid rocks from the Hanson Lake Block have been dated at about 2450 and 2410 Ma respectively by Rb-Sr methods (Coleman, 1970; Bell and Macdonald, 1982) and may be early Proterozoic unless the Rb-Sr age is too low. The Rottenstone - La Ronge Magmatic Belt comprises volcanogenic and plutonic rocks and was evidently developed at, or accreted to, the southeastern margin of older continental cratonic crust. It has been interpreted as a major 'Cordilleran-type' arc massif (Lewry et al., 1981; Lewry, 1981a).

Currently available geochronological data from the Hudsonian orogenic belt in Saskatchewan largely comprise Rb-Sr whole-rock measurements (e.g. Blenkinsop and Bell, 1981; Bell and Macdonald, 1982), with relatively very few U-Pb zircon determinations. Many of the Rb-Sr isochron ages of about 1700 to 1750 Ma probably date late Hudsonian intrusion of very late synkinematic or postkinematic plutons or, in deformed rocks, the waning of Hudsonian metamorphism. Compatible Rb-Sr and U-Pb zircon dates of about 1870 Ma for the Wathaman Batholith (Fig. 1; Ray and Wanless, 1980; Bell and Macdonald, 1982) and Rb-Sr ages from the La Ronge Belt (Watters, this volume) and Lynn Lake area, Manitoba (Clark, 1978; Clark and Cheung, 1977) indicate that major igneous activity may have occurred between 1850 and 1900 Ma ago. The study described here will utilize the often documented ability of zircons to retain primary crystallization ages; moreover, rocks such as tonalites and granodiorites commonly have abundant zircons, but Rb-Sr ratios that are too low for meaningful Rb-Sr age determination.

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Project given logistical support in Saskatchewan by Saskatchewan Energy and Mines.

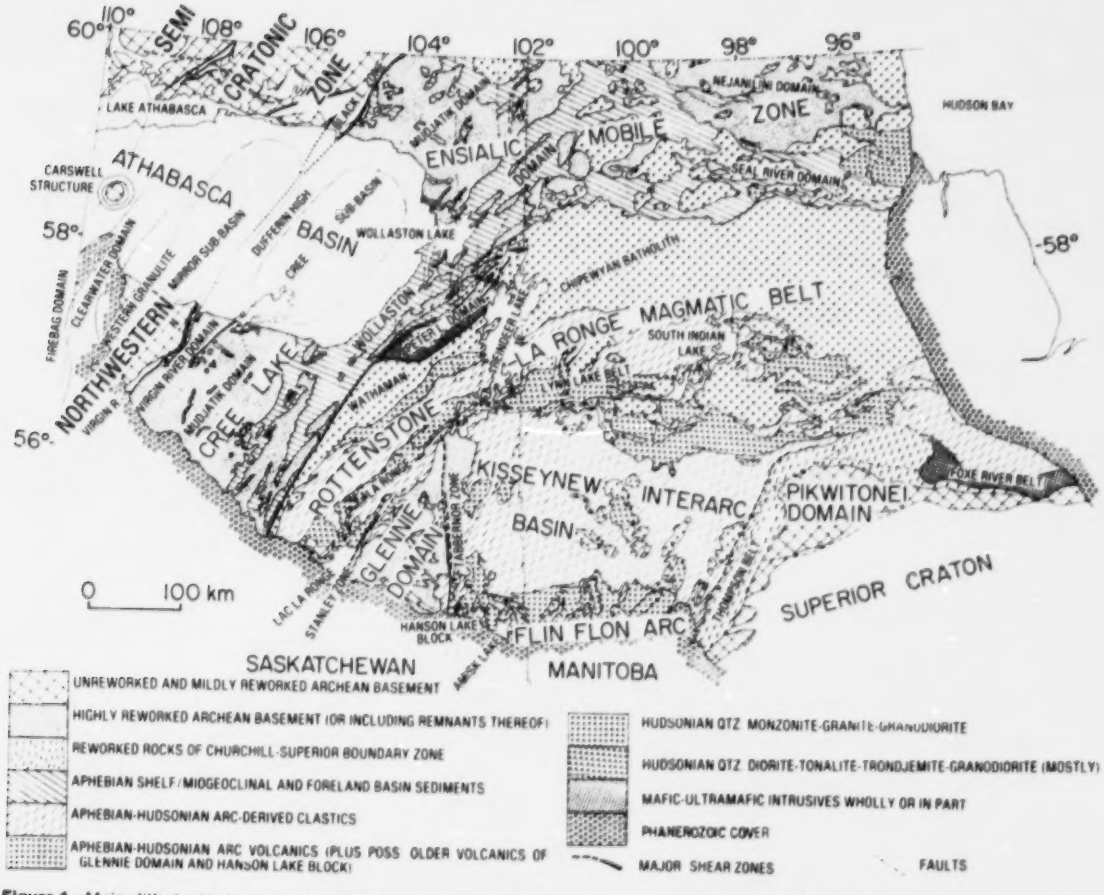

Figure 1 - Major lithotectonic elements of the southwestern part of the Trans-Hudson Orogen in Saskatchewan and Manitoba (from Lewry et al., in press).

In addition to providing a more detailed chronology for igneous events in the Hudsonian orogenic belt, this study will permit determination of the time relationships between the Trans-Hudson Orogen, the Wopmay Orogen to the northwest (Hoffman et al., 1982; Bowring and Van Schmus, 1982; Hildebrand et al., 1983) and the Penokean Orogen to the south (Van Schmus, 1980). These three orogenic belts all appear to have formed in the interval 1850 to 1900 Ma ago, suggesting a possible tectonic linkage and a period that had special significance in the evolution of the North American continent.

Rock Units Sampled

Samples collected during the summer of 1983 were taken to establish age control for certain key or high priority domains in the southeastern part of the orogen. They are listed below, with a brief discussion of their significance; approximate sample locations are given in Fig. 2.

Glennie Lake Domain and Hanson Lake Block

The question of whether these domains contain Archean elements is critical to their interpretation as microcontinents involved in collisional orogeny. Thus, collecting in these domains was of high priority. We have collected the following samples:

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[1]To obtain Saskatchewan Geological Survey sample code, substitute 8304 for HUD-83 (e.g. 8304-6 in this case).

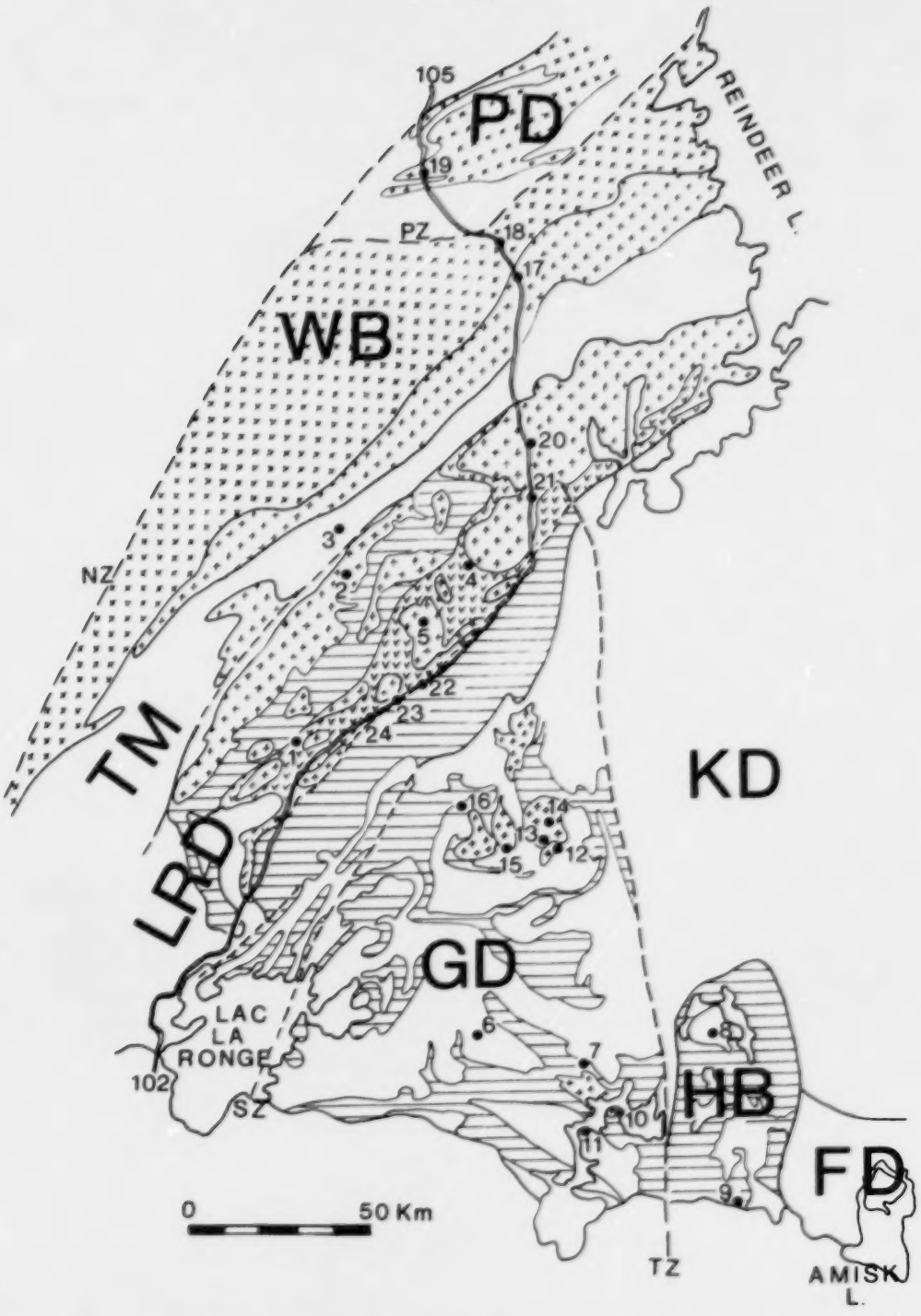

Figure 2 - Collection locations of samples discussed in text. Key: crosses, Hudsonian plutonic rocks; v-pattern, arc metavolcanics; horizontal line, undifferentiated supracrustal rocks; unornamented, undifferentiated older gneisses and plutonics of the Glennie Lake Domain and Hanson Lake Block; migmatites of the Tonalite-Migmatite Complex of the Rottenstone Domain; mafic-ultramafic rocks of the Peter Lake Domain; FD, Flin Flon Domain; HB, Hanson Lake Block; GD, Glennie Lake Domain; KD, Kisseynew Domain; LRD, La Ronge Domain; TM, Tonalite-Migmatite Complex of Rottenstone Domain; WB, Wathaman Batholith; PD, Peter Lake Domain; TZ, Tabbernor Zone; SZ, Stanley Shear Zone; NZ, Needle Falls Shear Zone; PZ, Parker Lake Shear Zone.

a) Samples from Glennie Lake Domain:

HUD-83-6[1] - Carroll Lake gneiss, possible basement to supracrustal rocks in the Glennie Lake Domain. Sample from south side of Carroll Lake (cf. Scott, 1981).

HUD-83-7 - Metarhyolite with phenocrysts of quartz and feldspar; represents supracrustals of Glennie Lake Domain. Sample from about 400 m north of the north side of Palf Lake (cf. Scott, 1981).

HUD-83-10 - Deschambault granite. Bell and Macdonald (1981) obtained a Rb-Sr age of about 1900 Ma. Sample from Deschambault Lake near the settlement (cf. Padgham, 1968).

HUD-83-11 - Tonalite. Sample from east side of Deschambault Narrows. This rock was previously sampled by Bell, but failed to produce an isocron (cf. Padgham, 1968).

HUD-83-12 - Wykes Lake pluton. Sample is biotite granodiorite from north end of Wykes Lake (cf. Lewry, 1977).

HUD-83-13 - Eyahpaise pluton. Sample is granodiorite to tonalite from north side of Eyahpaise Lake (cf. Lewry, 1977).

HUD-83-14 - Small circular pluton that intrudes Eyahpaise granodiorite. Sample is biotite granodiorite from shore of an unnamed lake northwest of Stevens Lake (cf. Lewry, 1977).

HUD-83-15 - Fine-grained leucocratic muscovite-biotite granite ('aplogranite') collected from north shore of Planinshek Lake. This granite body intrudes all older units (cf. Lewry, 1977).

HUD-83-16 - Sample of biotite-hornblende-quartz-feldspar 'Older Gneisses' that are intruded by, or grade into, the Eyahpaise granodiorite. Bell and Macdonald (1982) reported a Rb-Sr age of 1655±55 Ma. Samples from north part of Dirk's Lake (cf. Lewry, 1977).

b) Samples from Hanson Lake Block:

HUD-83-8 - Sahli granite (charnockite). Bell and Macdonald (1982) reported a Rb-Sr age of about 2510 Ma. Sample from north-eastern side of Sahli Lake (cf. Macdonald, 1974).

HUD-83-9 - Porphyritic metarhyolite. Sample collected on southwest side of Hanson Lake is representative of volcanic rocks of Hanson Lake Block. Coleman (1970) reported a Rb-Sr age of about 2450 Ma for these.

Rottenstone - La Ronge Magmatic Belt:

This belt was sampled extensively because the ages of igneous rocks in the primary magmatic arc should best date the duration of active orogenesis. An attempt was made to obtain samples of the earliest igneous products (volcanic rocks), variously foliated early tonalitic and granodioritic plutons, the Wathaman Batholith, and the apparently late- to post-kinematic granites, as follows:

a) Volcanics:

HUD-83-1 - Metarhyolite or metadacite from Laroque Lake (cf. Pearson and Froese, 1959).

HUD-83-4 - Meta-'felsite' from south end of Nistoassini Lake (cf. Harper, 1983).

HUD-83-23 - Metadacite or metarhyolite with quartz and feldspar phenocrysts. Collected along Highway 102, adjacent to northwest end of McLennan Lake (cf. Budding, 1955).

HUD-83-24 - Metarhyolite with abundant quartz and feldspar phenocrysts. Collected along Highway 102, adjacent to McLennan Lake (cf. Morris, 1961).

b) Early Tonalitic-Granodioritic Plutons:

HUD-83-3 - Tonalite from within Davin Lake Tonalitic Gneiss Complex. Sample from south of Deception Lake (cf. Gilboy, 1982).

HUD-83-5 - Quartz diorite to granodiorite of Brindson Lake Pluton, collected from north-northeast of Windrum Lake (cf. Miller, 1949).

HUD-83-17 - Tonalitic gneiss collected along Highway 105, northeast of Davin Lake (cf. Johnston, 1973).

HUD-83-20 - Granodiorite of Macoun Lake Pluton. Bell and Macdonald (1982) reported a Rb-Sr age of 1740±45 Ma. Sample collected along Highway 105 near north end of Purdey Lake (cf. Lewry et al., 1980a).

c) Wathaman Batholith:

HUD-83-18 - Sample of somewhat deformed granite of the Wathaman Batholith. Bell and Macdonald (1982) reported a Rb-Sr age of 1895±45 Ma for the Wathaman, and Ray and Wanless (1980) reported a

U-Pb age from zircons from this body of about 1865 Ma. Collected along Highway 105, northeast of Wathaman Lake (cf. Lewry et al., 1980b).

d) Post-Kinematic Granites:

HUD-83-21 - A granite carrying feldspar metacrysts that is similar to but less foliated than Macoun Lake Pluton. Collected along Highway 105, northwest of Fleming Lake (cf. Johnston, 1970).

HUD-83-22 -'Jaysmith Lake Granite', a high-level, almost totally undeformed granite. Sample collected along Highway 102 close to Jaysmith Lake (see Lewry, this volume).

HUD-83-2 - Hickson Lake Pluton. Bell and Macdonald (1982) reported a Rb-Sr age of 1730±30 Ma. Sample collected along shore of Hickson Lake (cf. Gilboy, 1982).

Peter Lake Domain:

This domain lies to the north of the Rottenstone - La Ronge Magmatic Belt between its northeastern extension and the Wollaston Domain to the northwest (Fig. 1). Rocks within the Peter Lake Domain include granitoids and metagabbro; they are separated from the Rottenstone - La Ronge Magmatic Belt by a major shear zone, the Parker Lake Shear Zone. Their age and relationship to the main magmatic arc is thus obscure. We took one sample of a granitoid.

HUD-83-19 - Granitoid of the Peter Lake Domain. Collected along Highway 105, west of Peter Lake (cf. Scott, 1971).

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Project 8318

Pelican Narrows Project

by L. O. Craig[1]

The Pelican Narrows Project study area is indicated on the location map. Field work took place in two parts of the Pelican Narrows map sheet area 62M-2(W) (Figs. 1 and 2). A geological map of the Pelican Narrows map sheet produced by the Saskatchewan Geological Survey (Macdonald, 1974, 1975) was used as a basis for the present investigation, with revisions as indicated by the author's observations.

Table 1 is a provisional summary of the stratigraphy, structural history and metamorphism of the area.

Deformational History

The structural features of the area are illustrated in Fig. 3. The earliest deformational event recognized in the area (D_1), is displayed by unit Is, which is strongly foliated. The adjacent intrusive unit Gd shows a moderate to strong foliation coplanar with the layers in unit Is. The foliation planes produced by D_1 are designated S_1. The S_1 surface presently strikes east-west and dips to the north. This S_1 surface has been folded and possibly tilted by later events.

The second deformational event produced a strong and pervasive effect upon the area, forming a S_2 foliation and L_2 lineation in the Sahli granite as well as in units Gg and Ga, and induced F_2 folds in the other units. These F_2 folds are commonly associated with an S_2 axial plane foliation which is most evident in unit Qb. F_2 folds are open and plunge moderately towards the north and northeast.

The third and last deformational event produced the intense folding and mylonitization in unit A. The S_3 layering planes in the mylonite strike north-northeast and dip steeply to the east. The associated F_3 folds have shallow-plunging hinges and irregular axial planes. The F_3 deformation was associated with or followed by a lowering of metamorphic grade. Adjacent to a zone of S_3 mylonite, hornblende gneisses contain idiomorphic grains of chlorite.

Geochronology

One whole-rock rubidium-strontium isochron has been previously determined from the area (Bell and Macdonald, 1982). The samples analyzed were collected from the northern part of the Sahli granite at the location indicated in Fig. 1. The isochron indicates an age of 2410±40 Ma. In the vicinity of the sample location, the Sahli granite has been extensively to partially recrystallized and shows a strong F_1 foliation. An initial $^{87}Sr/^{86}Sr$ ratio of 0.7056±0.0005 suggests that the Sahli granite contains a significant component of older crustal material. The Sahli granite could be older than the indicated age due to possible disturbance of the isotope systems by recrystallization of feldspars and the growth of new biotite, both of which appear to be related to the D_2 event.

It is reasonable to assume that the biotite gneiss unit Bp is part of the Kisseynew Gneisses which are considered to be Aphebian. Since the D_2 event has affected the Bp gneisses, this sets a maximum age for the D_2 deformation.

Discussion

Units Q and Bg are the oldest rock units in the area. The presence of quartz-rich bands suggests a possible sedimentary origin. These units appear to wrap around the Sahli granite and connect with less deformed gneisses to the south of the granite, which are also considered to be metasedimentary. However, unit Q has been repeatedly deformed and recrystallized, and possibly contains a significant amount of unrecognized igneous material. No original sedimentary structures remain, with the possible exception of some of the larger scale layering. Fig. 4 is a map of an outcrop of unit Q gneiss, the location of which is indicated in Fig. 1.

The Sahli granite (Units Go and Ga) intrudes unit Q gneiss. Although inclusions are hard

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[1]University of Saskatchewan. Project received field logistical support from Saskatchewan Energy and Mines.

to recognize because of the effects of the S_2 deformation, one clear example of an inclusion of Q gneiss in Sahli granite was found.

Textures and structures in the northern part of the Sahli granite are dominated by D_2 fabrics and structures. The present S_2 foliation was produced by granulation and recrystallization of feldspars and the growth of new biotite.

The southern portion of the Sahli granite has been much less affected by the D_2

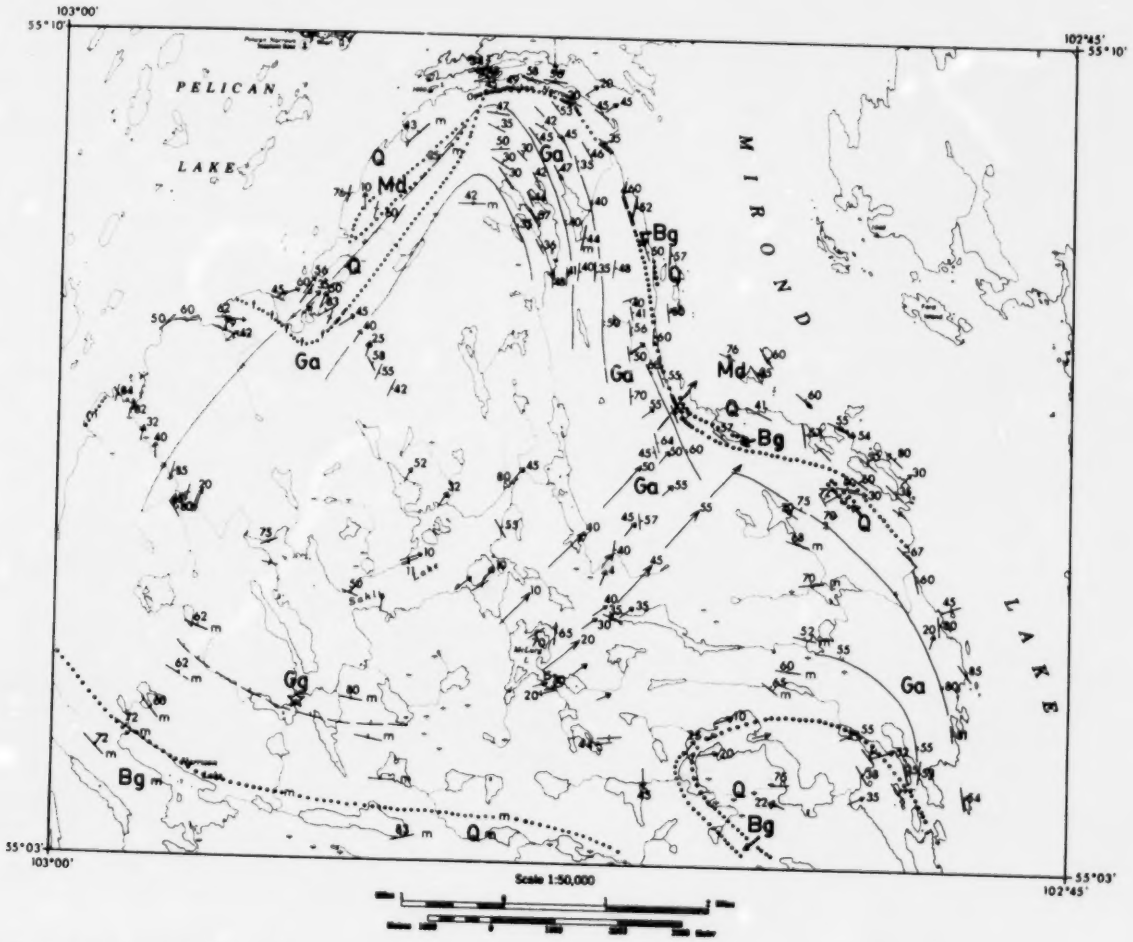

Figure 1 - Structures in the Sahli granite. Lithological units and some structural symbols adapted from Macdonald (1974):

Q **Quartzofeldspathic gneisses**: granoblastic to granitoid, layered and foliated, commonly containing layers and lenses of mafic gneiss; probably derived from felsic metasediments.

Bg **Biotite-garnet-sillimanite-cordierite gneiss**: commonly with quartz, feldspar, ± garnet, ± cordierite layers and metamorphic segregations, locally graphitic; probably derived from pelitic metasediments.

Md **Mafic dyke** or other small intrusive body.

Ga **Granitoid garnet-biotite gneiss**: with strong to moderate foliation, locally containing corroded clinopyroxene and traces of orthopyroxene.

Gg **Garnet-clinopyroxene-orthopyroxene-hornblende gneiss**: weakly layered and foliated, locally migmatitic, colour index varies from 5 to 15 percent.

Gd **Intermediate granitoid rock**: foliated grey to white, includes migmatites with hornblende gneiss paleosome.

Is **Rock**: strongly foliated to laminated, fine to medium grained, intermediate colour index.

Bp **Biotite gneiss** + garnet: medium grained, strongly foliated and layered to massive, commonly containing quartz and quartz-feldspar segregations, commonly gradational into Qp.

Qp **Felsic gneiss**: commonly containing traces of calc-silicate minerals.

A **Mylonitic gneiss**: strongly folded, containing lenses of units Bp, Qp and Gd, together with coarse-grained granite and pegmatite.

...f... boundary uncertain due to interfolding of units

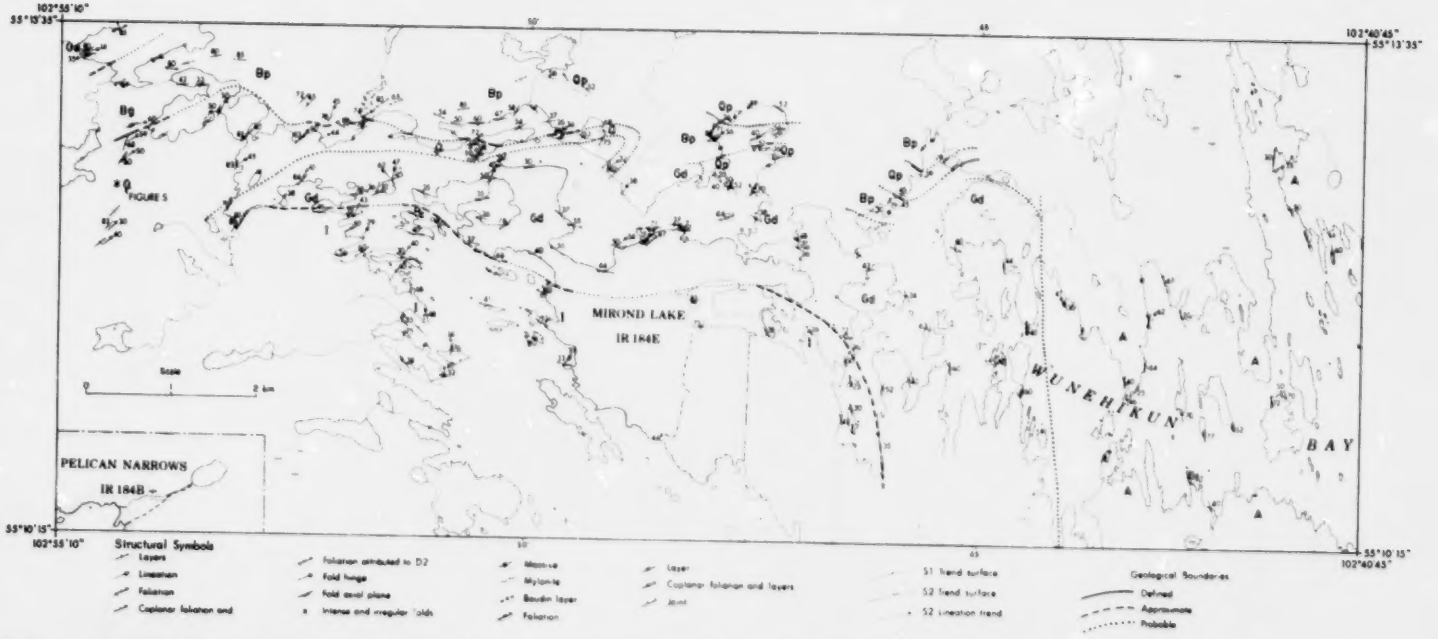

Figure 2 - Geology of the Wunehikun Bay area. Lithological units adapted from Macdonald (1974). Refer to Fig. 1 for explanation of units and symbols.

Table 1 - Provisional Summary of Stratigraphic Units, Deformation, Metamorphism and Geochronology

Stratigraphy, Wunehikun Bay Area	Stratigraphy, Sahli Granite Area	Deformational Events	Metamorphic Events	Geochronology
		D_3, F_3, S_3 mylonite	Chlorite growth in unit A	
	D_2 Md dykes ?	D_3, F_2, S_2 foliation L_2 lineation	Biotite-garnet assemblage in unit Ga	
Bp & Qp gneisses				Aphebian ?
	Md dykes			
Unconformity ?				
Unit Is		D_1, S_1 foliation and mylonites		
	Sahli granite Gg, (Ga)		Qpx, Cpx, garnet assemblage	c. 2.4 Ma
Gd possible intrusion (relation uncertain)	Intrusion			
Older gneisses Q, Bg	Older gneisses Q, Bg			possibly Archean

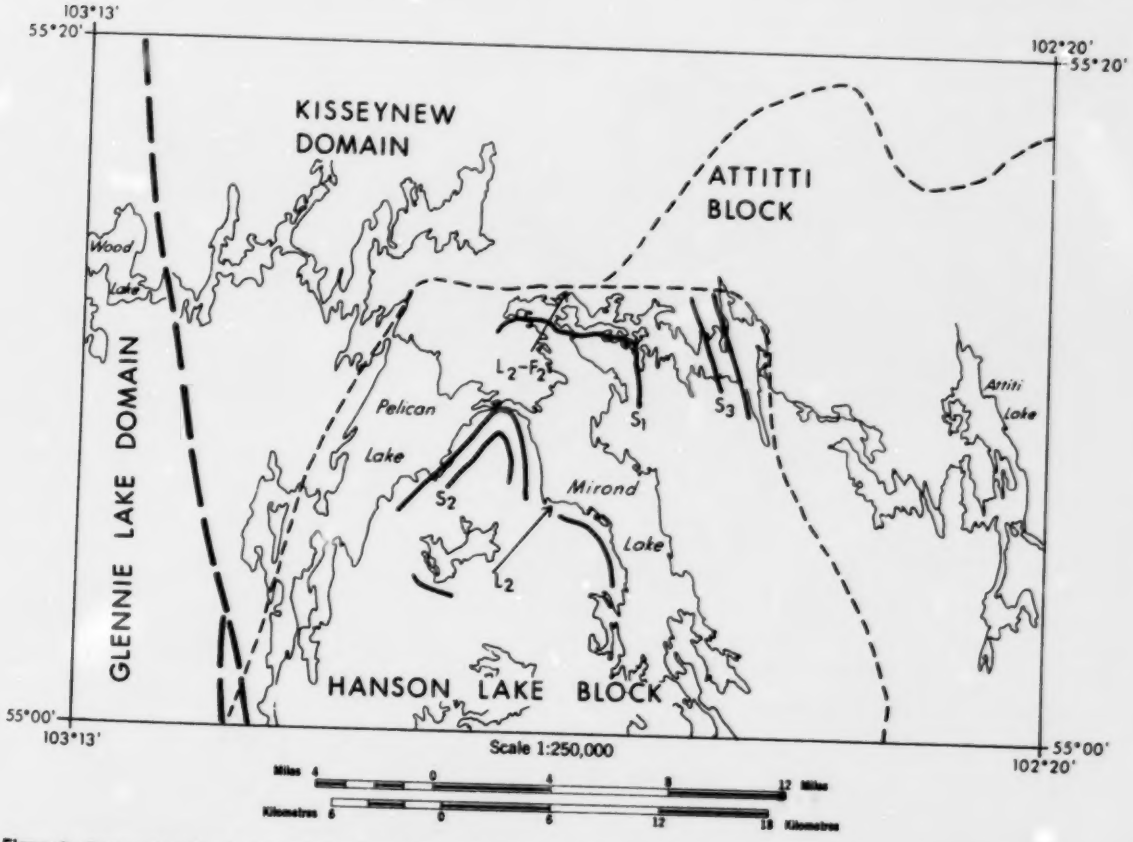

Figure 3 - Regional setting of structural features in the Pelican Narrows area. See text for designation of structural elements.

deformation. Fig. 5 is a detailed map of a group of particularly well exposed outcrops at the southwest corner of Sahli Lake. Orthopyroxene and clinopyroxene in these outcrops are moderately fresh. The rocks have a granular texture and only a weak and irregular foliation.

Economic Geology

Unit Bp and Qp gneisses north of Wunehikun Bay contain layers bearing disseminated iron sulphides and graphite. These layers are associated with calc-silicate minerals and are more siliceous than normal. Large

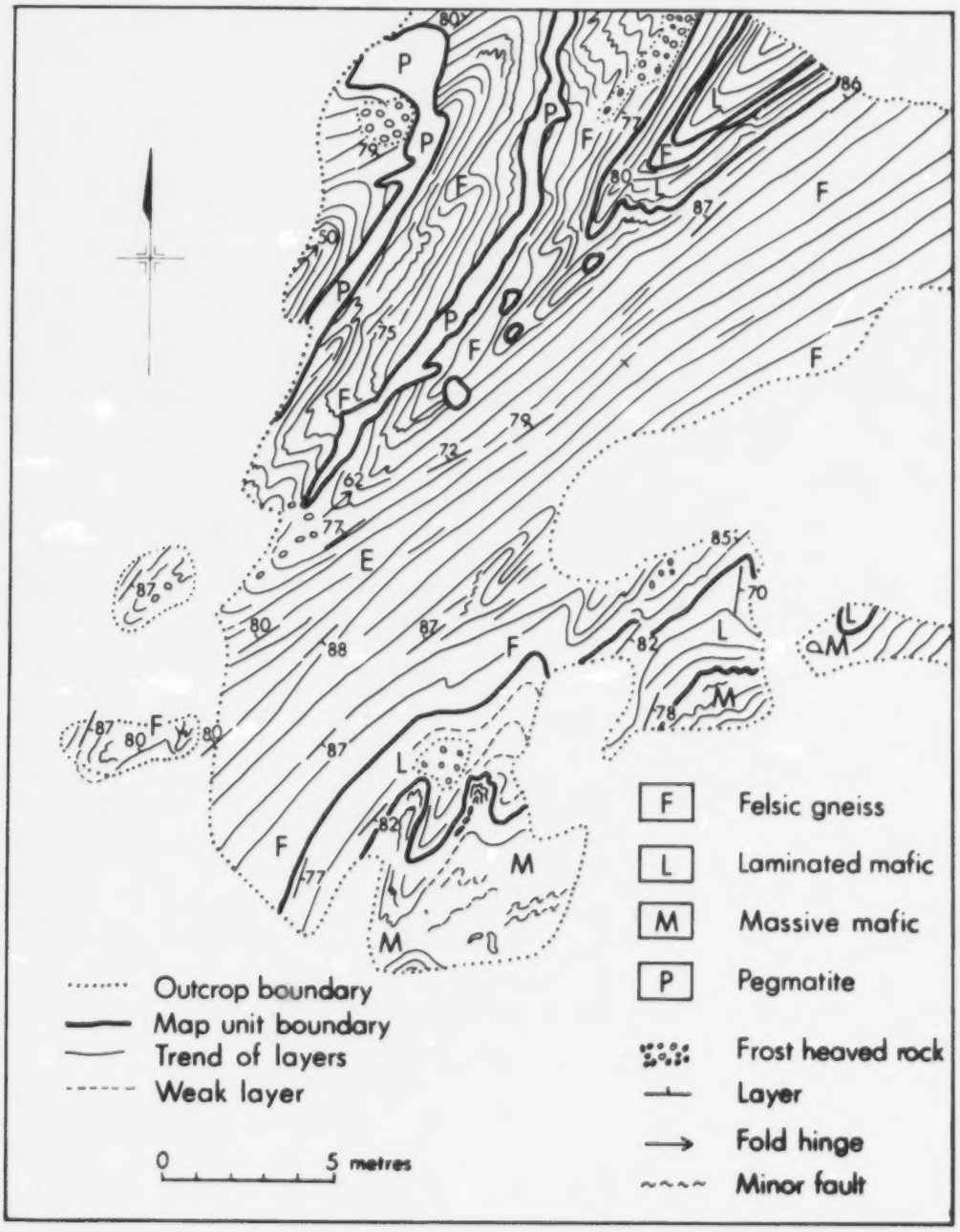

Figure 4 - Detailed map of a felsic gneiss outcrop (unit Q on Fig. 2).

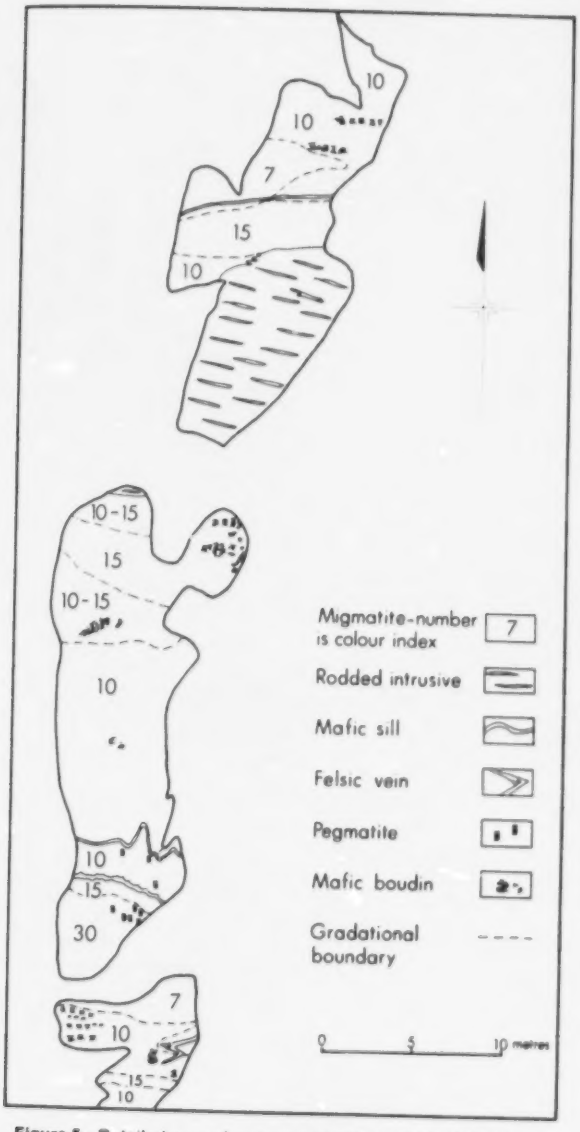

Figure 5 - Detailed map of an area of Sahli granite (unit Gg on Fig. 1).

patches of sandy till in the area immediately north of Wunehikun Bay contain significant quantities of iron-stained cobbles. The iron sulphide- and graphite-bearing gneisses strike eastward into unit A where they occur in lenses as tectonic relics. In the more highly deformed parts of unit A, the graphite is concentrated along S_3 planes. Although only iron sulphides were seen in outcrops visited, many sulphide-bearing layers beneath the till have not been examined.

Acknowledgments

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Project 8303

Sedimentological Study of the Martin Group

by Hugh E. Hendry[1]

The Martin Group of the Beaverlodge area was divided into four formations by Langford (1981). The lower three formations are, in ascending order, the Beaverlodge Formation, the Gillies Channel Formation and the Seaplane Base Formation, all three of which are conglomeratic. The uppermost formation, the Melville Lake Formation, is composed of bedded sandstone, siltstone and argillite, with only very small amounts of conglomerate. Tremblay (1972) considered that the deposits were continental, and Elliott (1982) postulated an alluvial fan and braided stream environment of deposition for the Gillies Channel Formation.

As a preliminary part of a study on the sedimentology of the Martin Group, outcrops were examined in the vicinity of Uranium City and Eldorado, and along the shores of Beaverlodge and Martin Lakes. The author was guided to the best outcrops by F. F. Langford.

Beaverlodge Formation

The Beaverlodge Formation overlies basement granites and gneisses. The surface of the unconformity is very uneven and is overlain in most places by conglomerate or breccia, or by interbedded conglomerates and siltstones or sandstones. In some places, clasts derived from the underlying basement are very angular and poorly aligned, and may represent rock-fall or talus deposits, but most of the basal conglomerate appears to be water-laid. Units many metres thick, of pebble to boulder, clast-supported conglomerate with a sandy matrix are common. Stratification generally is very poor and defined only by the parallel orientation of elongate clasts, or by boulder lenses. Imbrication is present but not common. At the Eldorado mine-site the basal conglomerate is interbedded with siltstone in units up to 30 m thick. The siltstones are thinly bedded and contain abundant ripple marks and wavy bedding, and are particularly well exposed on the slopes of Beacon Hill at the entrance to the Eldorado Mine.

The interlayering of conglomerates and siltstones close to the surface of the unconformity suggests that intermittent deposition of gravel from rock-falls and floods took place in a series of very small local basins where finer grained sediment accumulated in ponds. The considerable thickness of some of the siltstone units suggests that the loci of deposition of the fine-grained sediment may have been controlled by variations in the topography of the basement surface rather than by changing patterns of gravel deposition. Away from the unconformity, and stratigraphically above the interbedded conglomerates and siltstones, the rocks of the Beaverlodge Formation are well stratified and relatively well sorted. Well-bedded pebble to cobble conglomerates are interbedded with trough cross-stratified and planar cross-bedded sandstones. Within the sandstones, pebbles are concentrated at the bases of sets of cross-bedding or scattered along foresets; the presence of isolated boulders in some of the cross-bedded sandstone layers is evidence of highly competent currents. Thin layers of silt and very fine grained sand draped over the eroded tops of cross-bedded units are evidence of periodic stagnation. Within the Beaverlodge Formation sequences of beds show either a progressive upward increase in clast size and bed thickness, or a progressive upward decrease in clast size. Such sequences are on the order of several tens of metres thick, and may have been produced as a result of local tectonic activity contemporaneous with deposition.

Gillies Channel Formation

The basal conglomerate of the Gillies Channel Formation is poorly sorted and poorly bedded in the area studied by Elliott (1982). Further to the south, on the east side of Beaverlodge Lake, sorting is poor but bedding is well defined by thin sandstone lenses as well as by sets of trough cross-bedding.

The matrix of the conglomerate is sandstone or pebbly sandstone and the proportion of matrix varies from 30 to 50 percent over

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distances of only a few metres. Imbrication of pebbles and cross-bedding in the sandstones indicate flow from the north and northeast. All sandstone lenses and beds in the basal conglomerate contain floating clasts of pebbles, cobbles or boulders. The sandstones which form most of the Gillies Channel Formation are typically cross-bedded in sets up to 30 cm thick, with pebbles concentrated in layers along the bases of sets of cross-bedding; they are interbedded with thin layers of pebble conglomerate. Elliott (1982) has shown that these sandstones and conglomerates are arranged in a series of upward-fining sequences, which may represent individual flood cycles. The uppermost part of the formation, as defined by Langford (1981), consists of flaggy, cross-bedded and cross-laminated sandstones which are conglomeratic in places. Overall the Gillies Channel Formation shows a trend of decrease in clast size from bottom to top, which may be a result of shifting depocentres or gradual reduction of relief in the source area.

Seaplane Base Formation

The Seaplane Base Formation is texturally more diverse than any other part of the Martin Group. Interbedded conglomerates, sandstones, siltstones and pelites are exposed near the Norcanair waterbase on the shores of Martin Lake, and along the road to Predette Lake. The conglomerates are generally clast supported and, although sorting is variable, some beds are extremely well sorted; conglomerate beds are clearly defined and up to 3 m thick. The sandstones are very well bedded with both planar and cross-bedding, and display primary current lineation on some bedding planes. Conglomerate-filled scour channels up to 100 cm deep are common, and many of them contain pelitic clasts. Beds of pelite occur interbedded with conglomerates, and many conglomerate and sandstone layers are capped by thin drapes of mud. Irregularly shaped mud clasts indented by pebbles have been deformed during transport and incorporated in the conglomerates. Load casts have developed in some places where conglomerates overlie silt or mud. Many small-scale folds and faults that cannot be traced very far across the bedding indicate deformation of the sediment while it was still soft. Some of the muddy beds contain mud cracks, and the silts are wave rippled. Most of the structures in the Seaplane Base Formation point to conditions of great variability in current strength and duration, and periods of desiccation or formation of shallow ponds, accompanied by penecontemporaneous tectonism.

Melville Lake Formation

The Melville Lake Formation consists of siltstones, sandstones and pelites, with some very thin granule- or pebble-conglomerate lenses. Few are greater than 20 cm thick. Structures such as wave-ripple marks, mud cracks and sandstone dykes are common throughout the formation. Orientations of the crests of ripples are consistently north or northeast. Langford's (1981) interpretation of deposition of the sequence in ephemeral lakes seems reasonable in light of the evidence of repeated exposure of the sediments, and the lack of any channel deposits. The transition from the Seaplane Base Formation to the Melville Lake Formation takes place by a gradual decrease in the bed thickness of the sandstones and pebbly conglomerates.

Conclusions

After erosion of the basement surface, conglomerates and breccias were laid down in stream-flood and talus deposits, along with silts and pelites which accumulated in small ponds. When deposition had blanketed the irregular surface of the unconformity, coarse poorly-sorted conglomerates, well-stratified pebble conglomerates, cross-bedded pebbly sandstones and small amounts of silt were deposited in a gravelly braid plain to form the upper part of the Beaverlodge Formation. Small-scale upward-coarsening sequences within the Beaverlodge Formation may be the result of progradation after movement along faults marginal to the basin. The basal conglomerate of the Gillies Channel Formation may mark rejuvenation in the source area. The sandstone member of the Gillies Channel Formation shows little evidence of channeling, but abundant conglomeratic beds indicate high rates of flow and the sediments may have accumulated as sheet-like deposits on a broad, braided, alluvial plain. The presence of channel-fill deposits, interbedded conglomerates, sandstones and pelites, mud clasts and desiccation features in the Seaplane Base Formation indicates a transition to an environment in which systems of channels and sloughs were established, and is compatible with continued retreat of the sediment source. With the deposition of the Melville Lake Formation the basin reached a stage at which supply of gravel had diminished to almost zero, and the environment was one in which muds and sands were laid down in shallow ephemeral lakes.

The whole sequence may have been deposited during a long period of scarp retreat, with intermittent reactivation of faults causing

surges in supply of coarse material to provide the conglomeratic beds. Further evidence of tectonic activity during sedimentation is provided by the soft sediment deformation in the Seaplane Base Formation.

Detailed section measurement of all of the formations is required to establish the nature of textural changes through the section, and to determine the lateral relationships of the rock types. This will allow a better evaluation of the likely relative importance of depositional processes and contemporaneous tectonic activity in the development of the sequences.

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Character and Structural Relations of the 'McLennan Group' Meta-arkoses, McLennan-Jaysmith Lakes Area

by John F. Lewry[1]

Meta-arkoses and related rock types are shown as a semicontinuous belt (Fig. 1) extending throughout the northwestern part of the MacLean Lake and the northern part of the Kisseynew Domains of the Saskatchewan Precambrian Shield (Macdonald and Broughton, 1980). Generally, they are structurally overlain to the northwest by metavolcanic rocks and associated plutons of the La Ronge Domain. Their age relative to the La Ronge domain is currently debatable. This season's work has shown that the meta-arkoses are probably all of closely similar age and may belong to one major stratigraphic unit, for which the name McLennan Group is here proposed. Their extent and structural context are relatively well known in the southwest part of the MacLean Lake Domain (Padgham, 1960, 1963; Abraham and Lewry, 1981) but hitherto poorly established in much of the region northeast of Dickens Lake (Fig. 2).

Just over four weeks of the 1983 field season were spent in redefining and remapping the McLennan Group in the segment extending from Dickens Lake northeastwards to just east of Jaysmith Lake (Fig. 2; accompanying map). The work concentrated on the junction relations between the group and adjacent rocks of the La Ronge Domain. The area examined includes parts of the Settee Lake (west half) (Morris, 1961), Settee Lake (east half) (Budding, 1955) and Windrum Lake (Miller, 1949) map areas. Roadside exposure in the southern Brabant Lake area (Kirkland, 1959) was also examined.

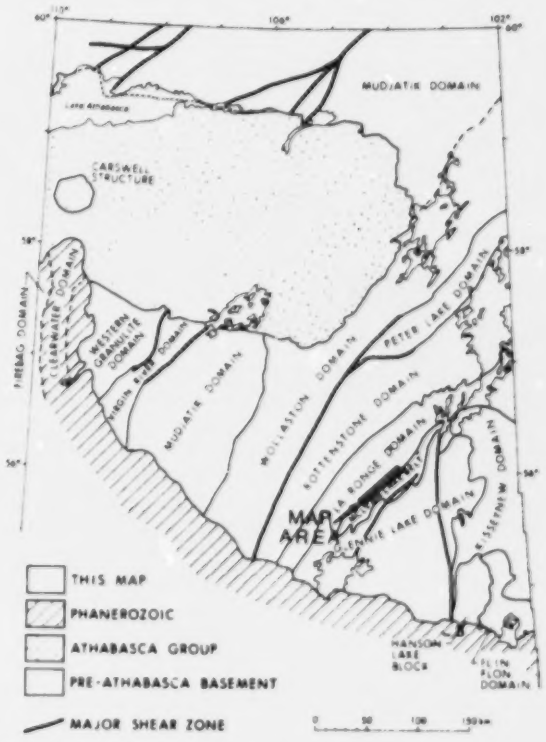

Figure 1 - Approximate location of map area.

Extent and Character of the McLennan Group

The current work has established that the meta-arkoses, together with their anatectic and tectonised derivatives occupy a continuous belt extending from a previously mapped southward-closing termination in the Haugen Lake synform (Padgham, 1960; Abraham and Lewry, 1981) (Fig. 2) northeastwards to at least 5 km east of Jaysmith Lake, where they either disappear or continue as the thin granitoid meta-arkose units mapped by Kirkland (1959) in the southern Brabant Lake area.

In the Settee Lake (west) area, the McLennan Group includes rocks previously designated 'granitic gneisses', 'gneissic granite' and 'undifferentiated metasedimentary rocks' (unit 2 and units 9b and 1, in part, of Morris, 1961). In the Settee Lake (east) and Windrum Lake areas, the group incorporates units hitherto termed 'granite and granodiorite' (unit 7, in part, of Budding, 1955, and units 8b, c, in part, of Miller, 1949). Throughout this segment of the belt variably tectonised members of the McLennan Group are in abrupt contact with the La Ronge Domain, save in the area east of Jaysmith Lake where biotitic gneisses locally intervene.

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Most of the metasedimentary paleosome in the central and southeastern parts of the belt comprises leucocratic, red, pink or cream, medium- to coarse-grained, poorly foliated to massive granitoid meta-arkose, characterised by the impersistent but widespread occurrence of prominent quartz-sillimanite lenses (faserkiesel). The granitoid matrix consists mainly of quartz and K-feldspar with subordinate to minor plagioclase. Biotite is generally minor or absent but locally forms over 5 percent of the rock. Sillimanite forms sparse to abundant, grey-white faserkiesel, which commonly range up to 6 by 1 cm, and locally up to 15 by 3 cm, in cross-sectional size. In places the unit

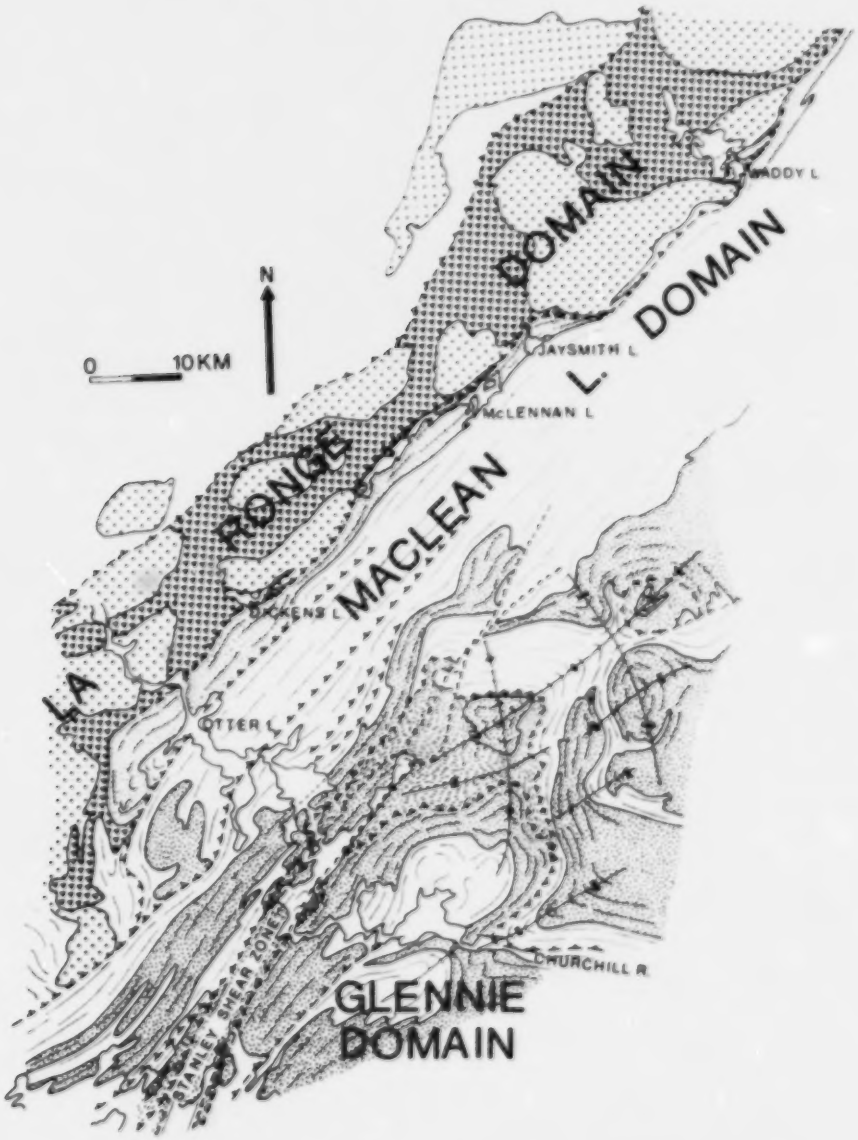

Figure 2 - General geology of the southwestern parts of the La Ronge, MacLean Lake and Glennie Domains. Explanation of symbols: open triangles - metavolcanics of the La Ronge Group; crosses - plutons in La Ronge Domain; stipple - meta-arkoses of the McLennan Group; random ticks - indifferentiated granitic rocks and 'older gneisses' of Glennie and MacLean Lake Domains; short dash pattern - tectonic schists of the Stanley Shear Zone and its' folded extensions in the Glennie Domain; unornamented - indifferentiated supracrustal rocks of the MacLean Lake and Glennie Domains. Established and likely thrusts and shear zones are indicated by dashed lines with barbs in direction of dip.

includes from 2 to 10 percent, and locally up to 15 percent, sillimanite lenses, occurring either throughout the outcrop or in restricted bands. Muscovite is generally absent or is a minor constituent, but locally sheaths sillimanite lenses. Primary layering is locally defined by faint colour or compositional banding and/or regular alternation of sillimanite-rich and sillimanite-poor bands up to 1 m or more in thickness. Foliation is generally overprinted and variably obscured by later granoblastic recrystallisation. Micas are poorly oriented and the granitoid matrix is essentially massive in much of the area, though foliation is still defined in places by prominent planar and linear preferred orientation of faserkiesel, which in three dimensions have a highly triaxial ellipsoidal shape. Planar fabric is variously parallel or oblique to primary layering, indicating the presence of tight coeval folding.

Northwestern parts of the McLennan Group consist mainly of less granitoid, medium- to fine-grained, better layered meta-arkose, arkosic greywacke and arkosic quartzite. These variously red, pink, grey-pink or grey rocks typically have a regular, strongly developed, slabby or flaggy foliation which is generally parallel or slightly oblique to compositional layering and is commonly accentuated by thin muscovite-rich folia and partings. Some coarser granitoid variants lack muscovite but in general this mineral is a prominent constituent. Biotite is generally absent or minor in amount but abundant in some arkosic greywacke units.

Arkosic wacke and quartzite units are generally grey. However, most 'grey gneisses' typically occur close to the junction with rocks of the La Ronge Domain and are notably finer grained and more intensely foliated than the remainder of the succession; as discussed below, they are generally interpreted as more intensely deformed meta-arkoses, rather than distinct compositional variants. Richly muscovitic arkosic schists, occurring in some localities immediately adjacent to the domain junction, are also thought to owe their character largely to tectonic modification of more 'normal' meta-arkoses.

Sillimanite was identified only locally in the northwestern parts of the belt, either as fine fibrolitic mats along foliation surfaces or less commonly in units containing abundant small faserkiesel; in both cases sillimanite is partially or completely replaced by muscovite. Such sillimanite occurrences persist all across the belt, even in outcrops immediately adjacent to the northwestern junction.

Arkosic polymictic metaconglomerates were unequivocally identified in only one locality (about 500 m northwest of the north end of Jaysmith Lake) close to the contact with La Ronge Group metavolcanics where they persist for at least 150 m across strike. They contain plentiful flattened and elongate pebbles and cobbles in an ill-sorted gritty arkosic or arkosic wacke matrix. Clasts vary from small pebbles up to a maximum observed size of approximately 25 by 10 by 5 cm, are generally well rounded and comprise varied granitic lithologies, quartz and subordinate highly flattened, black metavolcanic and amphibolite fragments. The matrix is mostly arkosic but locally is rather mafic and hornblende bearing. Crude to regular layering is defined both by variation in size and abundance of clasts and compositional variation of the matrix. The contact with metavolcanics was not seen and the source of volcanic and granitic clasts is uncertain. The full extent of the unit was not established. Pebbly units were locally identified elsewhere in the McLennan Group but most apparent 'metaconglomerate' layers appeared to be tectonically derived by attenuation and disruption of quartz and pegmatite veins.

About 50 percent or more of the exposed McLennan Group consists of massive to gneissic pink pegmatite and granite neosome, typically forming large and small irregular sheets trending approximately parallel to foliation.

La Ronge Domain

Rocks of the La Ronge Domain were examined in detail mainly in areas close to their junction with the McLennan Group, along the highway and in a limited number of wider ranging traverses. Previously mapped lithological boundaries were modified only slightly in the Settee Lake (west) area. In the Settee Lake (east) area, however, the supracrustal belt parallel to the northwest shore of McLennan Lake consists largely of intensely foliated meta-arkoses. The narrow strip of metavolcanic rocks to the northwest of these appears to wedge out to the northeast, between the McLennan Group and the Fork Lake pluton. Conversely, metavolcanic rocks are more extensive than previously indicated (Budding, 1955; Miller, 1949) in the area north and west of Jaysmith Lake and are in contact with the McLennan group over a distance of 8 or 9 km between the Fork Lake and Brindson Lake plutons.

Less deformed metavolcanic rocks of the La Ronge Group comprise basic to intermediate lavas, agglomerates and layered tuffs with

subordinate interlayered felsic volcanics, epiclastic rocks and tuffaceous metagreywackes; they are well described by previous workers. Though strongly deformed, such rocks generally retain primary volcanic and depositional features. All rock types become progressively more deformed towards their contact with the McLennan Group, with diminution of grain size, intensification of a very regular flaggy to schistose foliation and obliteration of all but gross primary features, as described below.

Plutonic rocks occur in three major intrusions, the Bervin Lake, Fork Lake and Brindson Lake plutons. All intrude the La Ronge Group and have been previously described as comprising a variety of rock types ranging from diorite to granite. In the areas examined by the present writer, the Bervin Lake and Fork Lake plutons mostly comprise pink to grey, medium- to coarse-grained, hornblende-quartz monzodiorite or granodiorite. The Brindson Lake pluton on the other hand comprises a generally coarser grained, quartz-rich, biotite granodiorite-granite. All three plutons tend to be weakly foliated or massive in their interiors but are progressively more highly deformed to the southeast, closer to the McLennan Group. Limited observation indicates that such 'contact strain' is much less pronounced in marginal zones remote from the southeastern boundary of the La Ronge Domain.

MacLean Lake Domain[2]

Rocks of this domain were observed only near their junction with the McLennan Group to the southeast and in a limited number of traverses south and east of Jaysmith Lake. They are a monotonous assemblage of highly migmatised and injected psammitic to semipelitic metagreywacke 'biotite gneisses', with subordinate pelites and intercalated zones of hornblendic, amphibolitic and calc-silicate gneisses. Primary layering, including delicate compositional lamination and graded bedding, was locally observed, but primary features are generally obliterated. The metagreywackes typically contain 10 to 25 percent biotite in a quartz-plagioclase-minor potassium feldspar, granoblastic to granitoid, medium- to coarse-grained matrix. They are sporadically garnetiferous and locally contain fibrolitic sillimanite. In general, the paleosomal components of the complex are similar to the metagreywacke-hornblende gneiss assemblage which forms the bulk of the MacLean Lake Domain in the Otter Lake area to the southwest (Padgham, 1960, 1963; Abraham and Lewry, 1981), but are more highly recrystallised and probably constitute a more injected and higher grade equivalent. Limited observations farther to the northeast, however, suggest to the present writer that cordierite-garnet-sillimanite gneisses ('Kisseynew Gneisses') forming much of the southeastern part of the domain in the Brabant Lake area (Kirkland, 1959) are a generally more pelitic assemblage rather than simply a more highly metamorphosed equivalent of the 'biotite gneisses'.

Fifty percent or more of outcrop area in the biotite gneiss complex comprises granitic to locally tonalitic neosome, mainly as complex pervasive, massive to strongly gneissic pegmatitic bodies which grade locally into finer grained leucogranite.

The Jaysmith Lake granite is a coarse-grained massive homogeneous red leucogranite. The body is up to 600 m wide and well exposed in roadside outcrop. Along strike to the northeast and southwest it appears to interfinger with and grade into massive pegmatite and migmatitic gneisses, and is no longer separately defined. The granite has discordant intrusive relations with highly deformed biotite gneisses and clearly postdates major regional thermotectonism. As such, it was sampled for U-Pb (zircon) dating (cf. Bickford et al., this volume) and should provide a minimum age constraint on the main 'Hudsonian' orogeny in the area.

Structure

Most supracrustal rocks have a moderate to intense, gneissic to schistose foliation, generally striking northeast to east and dipping moderately to steeply to the northwest or north. Major plutons are generally weakly foliated, save in areas near the southeast margin of the La Ronge Domain, but are evidently early synkinematic or prekinematic in age. Moderate to intense mineral lineation, rodding and subdomainal linear extension are prevalent. These linear elements generally lie within the foliation and plunge to the north or northwest. Such pervasive 'downdip' extensional linear fabrics have previously been noted as a characteristic feature of the MacLean Lake Domain and adjacent parts of the La Ronge Domain.

Two generations of tight to isoclinal minor folds, one coeval with regional foliation,

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[2]or MacLean Lake Belt (Macdonald and Broughton, 1980)

the other refolding it, can locally be identified but are not common. Major isoclinal closures are plentiful in the MacLean Lake biotite gneiss complex, as indicated by airphoto trends and outcrop patterns, but could not generally be identified in the McLennan Group or La Ronge Domain. One major closure occurs in biotite and calc-silicate gneisses southeast of the northeast part of McLennan Lake. Airphoto trends indicate the possible presence of another closure in meta-arkoses near the central part of McLennan Lake. Termination of the meta-arkoses east of Jaysmith Lake may possibly be related in part to an eastward-closing isoclinal fold.

Junction Relations of the La Ronge Domain and McLennan Group

The contact between meta-arkoses of the McLennan Group and rocks of the La Ronge Domain is invariably abrupt. Within a restricted zone on either side of the junction all rocks are notably more intensely foliated than elsewhere. This is most obvious in the Bervin Lake, Fork Lake and Brindson Lake plutons. Generally there is a gradual systematic passage from weakly foliated to strongly gneissic fabric; however, parts of the southeast margin of the Bervin Lake pluton display markedly inhomogeneous strain resulting in 'pseudoconglomeratic' zones which are typified by rotated lensoid blocks of gneissic granodiorite and disrupted quartz veins in a fine-grained gneissic to blastomylonitic groundmass.

Within about 500 m of the junction, mafic metavolcanics of the La Ronge Group are progressively converted to fine-grained black amphibolitic schists, and felsic units acquire an intense flaggy to mylonitic foliation. The black amphibolites were apparently distinguished as unit 6a (in part) by Morris (1961), who suggested that they might represent a distinct primary volcanic unit defining the southeastern boundary of the metavolcanic belt. They are here interpreted as tectonic schists derived in most cases from otherwise unremarkable basic metavolcanic rocks. Highly deformed to mylonitic felsic volcanics locally occur southeast of the black amphibolites and were formerly incorporated in Morris's unit 1 'mixed metasediments'. They are generally distinguished from the meta-arkoses by local occurrence of streaked-out quartz and feldspar phenocrysts, prevalence of biotite, local interlayering of hornblendic units and total lack of muscovite or sillimanite.

The junction zone is characterised in the McLennan Group by arkosic muscovite schists and increasingly fine-grained to aphanitic grey flaggy to 'slaty' submylonitic to mylonitic derivatives of the meta-arkoses.

Large-scale discordance and truncation of lithological boundaries is evident on both sides of the boundary shear zone. Major plutons of the La Ronge Domain are clearly truncated at the junction and were nowhere observed to intrude the McLennan Group. To the southeast, the layered meta-arkoses (unit 1B) intervening between the junction and the granitoid meta-arkoses (unit 1A) vary markedly in width along strike; this, plus the apparent impersistence of the metaconglomerates northwest of Jaysmith Lake, suggests that major parts of the McLennan Group succession may be cut out along the junction. Regional foliation trends and possibly even major fold traces on either side of the shear zone are locally highly oblique to the junction, suggesting that major movement along the zone postdates at least one major deformational event.

Discussion and Regional Implications

The relationships described above show that a major tectonic discontinuity separates meta-arkoses of the McLennan Group from structurally overlying rocks of the La Ronge Domain, both in the Dickens-Jaysmith Lakes segment and probably also farther to the southwest. This discontinuity is here termed the McLennan Lake Thrust. The attitude of linear fabric elements within and outside the shear zone suggests that the junction is a high-angled thrust or limb slide along which allochthonous rocks of the La Ronge Domain have been carried across the tightly folded McLennan Group. General relations between the shear zone fabric and foliation in adjoining areas, plus the noted retrogression of early sillimanite in areas close to the junction, suggest that at least part of the major displacement occurred during later stages of main regional deformation. The thrust evidently postdates emplacement of major plutons in the La Ronge Domain and may result largely from gross domainal differences in lithological homogeneity and structural anisotropy. The magnitude of movement and the extent of cutting out of the McLennan Group along the thrust are presently unknown.

The relative age of the McLennan Group and the rocks of the La Ronge Domain is not conclusively established. The presence of plutonic and volcanic clasts in arkosic metaconglomerates adjacent to the La Ronge

rocks is suggestive but not conclusive evidence that the arkoses are younger. Previously documented way-up data from meta-arkoses elsewhere in the MacLean Lake and Kisseynew Domains are sparse, ambivalent and even contradictory; they are unlikely to prove decisive, in view of established isoclinal folding and discordant tectonic junction relations. However, the character of the Haugen Lake synform (Abraham and Lewry, 1981) and the nature of the eastward termination of the arkoses east of Jaysmith Lake, considered in the context of large-scale isoclinal folding, suggest that the McLennan Group occupies the core of a complex overturned regional synform. The northwestern limb of this synform is bounded and perhaps discordantly overridden by the McLennan Lake Thrust, implying that the McLennan Group is younger than the La Ronge Group metavolcanics.

There are obvious similarities between major lithological assemblages in the MacLean Lake and La Ronge Domains and those in the Lynn Lake area of Manitoba, where arc metavolcanics of the Wasekwan Group are shown to be unconformably overlain by younger meta-arkoses of the Sickle Group (Campbell, 1972; Zwanzig, 1977). The Sickle Group is lithologically very similar to the McLennan Group and lies along the same semicontinuous regional belt, though complete lateral continuity is not presently established. In view of the structural relations described above, there seems little reason to resist the conclusion that the two groups are equivalent in age, despite locally conflicting younging data and the general structural inversion prevailing in most of the Saskatchewan segment of the orogen. Truncation of early plutons at their junction with the McLennan Group may in part reflect original unconformity, albeit highly modified and largely obscured by later tectonic dislocation.

The extent and degree of continuity of the McLennan Group in the region to the northeast between Jaysmith and Reindeer Lakes is uncertain. However, meta-arkoses appear to be more extensive than is generally indicated by regional mapping. Examination of roadside exposure suggests that most of the 'leucocratic biotite-muscovite granodiorite' (unit 6b of Kirkland, 1959) extending through Lindsay Lake towards the north end of Brabant Lake is in fact granitoid meta-arkose. The same may be true of other rocks originally mapped as granites or incorporated in mixed metasedimentary units in the Waddy Lake area (cf. Johnston, 1969; Fox and Johnston, 1980).

The McLennan Lake thrust is only one of a number of regional thrust and shear zone discontinuities recently identified in the La Ronge and MacLean Lake Domains (Fig. 1). These together indicate major thrust stacking and immense structural telescoping across this part of the Hudsonian Orogen. It is tentatively suggested that parts of the northwestern margin of the La Ronge metavolcanic-plutonic belt, where there is local documentation of major shearing and apparent truncation of plutons, may also be defined by major tectonic dislocation and that much of the volcanic-plutonic belt may be an allochthonous slice.

Economic Geology

Most gold mineralisation in the La Ronge Domain appears to be spatially related to felsic volcanic units and/or plutons, with or without additional structural control. Available published information indicates that such mineralisation in the Star Lake area, just north of McLennan Lake, occurs in quartz veins related to a zone of shearing close to the junction between metavolcanics and the Fork Lake pluton. Massive quartz veins containing sparse sulphide mineralisation were noted during this investigation in the vicinity of the McLennan Lake Thrust near the southwest end of McLennan Lake. In view of these data, it is felt that the thrust zone may warrant closer investigation for economic potential.

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Geochemistry and Geotectonic Setting of Meta-igneous Rocks, Combe Lake Area

by B. R. Watters[1]

It has been suggested that lower units of the supracrustal succession occurring in the Courtenay-Cairns Lake belt along the southeastern margin of the Wollaston Domain may represent a basic to intermediate volcanic, intrusive and sedimentary suite related to early continental rifting (Ray and Wanless, 1980; Lewry et al., 1981). These supracrustals consist of immature meta-arkoses, polymictic metaconglomerates and interbedded basic metavolcanics (Scott, 1970; Coombe, 1977). Metamorphic grade is mid to upper amphibolite facies with local retrogression to greenschist facies (Ray and Wanless, 1980).

In developing a model for possible plate tectonic evolution of the Wollaston Domain and the adjacent Peter Lake Domain and Rottenstone - La Ronge magmatic belt (Fig. 1), Ray and Wanless (1980) and Lewry et al. (1981) have proposed deposition of a 'lower arkosic unit' and basic volcanics during the beginning stages of very early Aphebian rifting of Archean continental crust, followed by the development of oceanic lithosphere and deposition of continental margin-type sediments of the Wollaston Group. Subsequent early Hudsonian subduction and evolution of a volcano-plutonic arc complex is represented by the Rottenstone-La Ronge magmatic belt.

The aim of the present study was to determine the geochemical characteristics of meatvolcanic rocks from the Courtenay-Cairns Lake belt so as to test the hypothesis that they were generated and emplaced in a continental rift regime. Six samples of metavolcanic rock were determined. In addition, eight samples of mafic meta-intrusives were analyzed from the adjacent Peter Lake Domain immediately to the southeast (Figs 1 and 2; Table 1), on the possibility that they are genetically related to the extrusives. These samples and Fig. 2 were provided by B.P. Scott. Volcanic terminology has been used in the following account.[2]

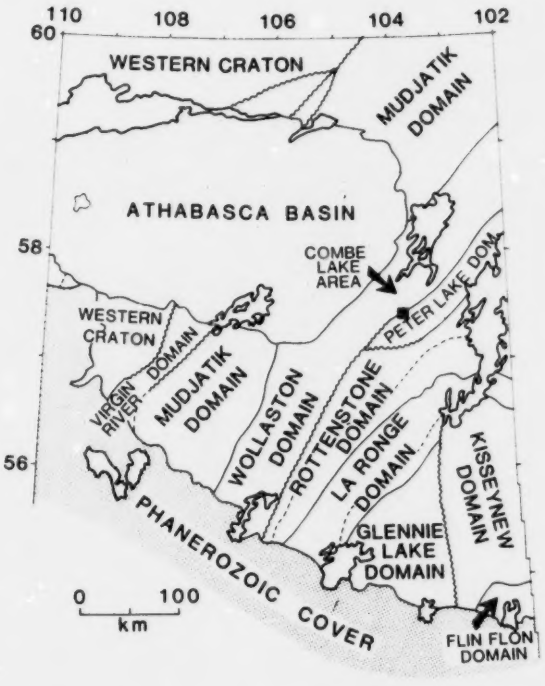

Figure 1 - Major subdivisions of the Churchill province in northern Saskatchewan (after Lewry and Sibbald, 1977) and the location of the Combe Lake area.

Geochemistry

In terms of silica content the rocks range from basaltic to andesitic, with the majority falling into the basaltic (45 to 53 percent SiO_2) and basaltic-andesitic (53 to 56 percent SiO_2) groups.

The classification of metamorphosed igneous rocks using major element concentrations,

[1]Department of Geology, University of Regina. Project funded by NSERC operating grant A 7418 to B. R. Watters; samples provided by the Saskatchewan Geological Survey.

[2]Editor's note: The combined extrusive and intrusive samples are referred to as the 'Combe Lake suite' in this report. Although the author has not distinguished extrusive and intrusive rocks in this account, the plots appear to show a genetic relation which raises further important implications for the tectonic history of the region and which will undoubtedly call for further comment.

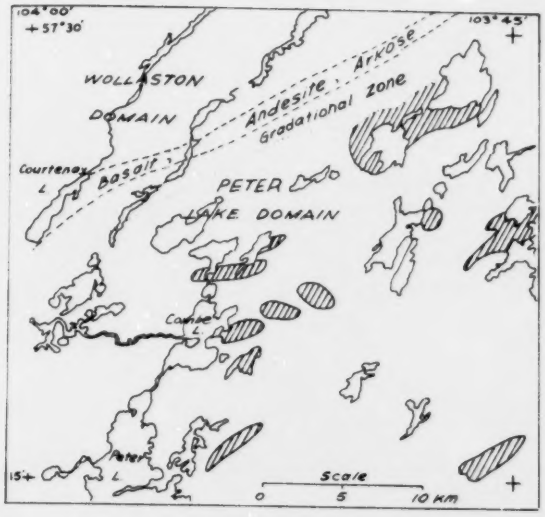

Figure 2 - Detail of sample area. Metavolcanic rocks of the Courtenay-Cairns Lake belt and mafic intrusive plutons in the Peter Lake Domain (shown as ruled areas). Figure provided by B.P. Scott.

particularly those of the more mobile alkali elments, is often unreliable due to element migration during metamorphism or metasomatism. Plotting the Combe Lake suite on the alkali igneous spectrum diagram of Hughes (1972) suggests that some of the samples have suffered changes in alkali content, specifically a relative depletion of Na_2O (Fig. 3). A ternary plot of the normative constituents An, Ab and Or (Fig. 4) indicates that all the 'altered' specimens fall into the K-rich field of the diagram, supporting the suggestion that the changes have involved a depletion of Na and relative enrichment of K. The majority, however, fall within or close to the 'field of unaltered igneous rocks' in Fig. 3 and the 'field of average rocks' in Fig. 4 and have apparently not suffered large changes in total alkali content or K/Na ratios.

A plot of SiO_2 vs. total alkalis (Fig. 5) indicates that the suite is largely subalkaline, the majority falling into the high alumina (calc-alkaline) field of Kuno (1966). Notably, those samples determined to be altered on the alkali igneous spectrum diagram (Fig. 3) display the largest scatter, and plot in peripheral positions. The majority of samples from the Courtenay Lake suite (Table 1) are high in Al_2O_3 (x = 16.56 percent) and low in TiO_2 (x = 0.92 percent), both important characteristics of calc-alkaline rocks.

The classification of the suite as dominantly basaltic to basaltic-andesitic and mainly

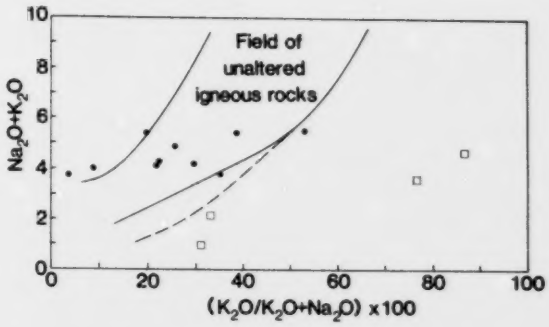

Figure 3 - Alkali igneous spectrum diagram of Hughes (1972) for the Combe Lake suite. Field of unaltered igneous rocks has been extended by the dashed line to include island arc tholeiites (after Stauffer et al., 1975). Samples considered to be significantly altered have been distinguished by means of squares; relatively unaltered samples are represented by dots.

subalkaline is supported by the plots SiO_2 vs. Zr/TiO_2 (Fig. 6) and SiO_2 vs. Nb/Y (Fig. 7). The ratios of Zr/TiO_2 and Nb/Y are not often affected by metamorphism since the elements involved are immobile and serve as more reliable indicators of alkalinity than $Na_2O + K_2O$ as used in Fig. 5. It could also be argued that during metamorphism to upper amphibolite grade some migration of silica might also have occurred. A plot of Nb/Y vs. Zr/TiO_2 (Fig. 8) using only immobile elements, as suggested by Winchester and Floyd (1977), also characterizes the suite as essentially subalkaline and basaltic to basaltic-andesitic, suggesting as a corollary that silica has also remained relatively immobile.

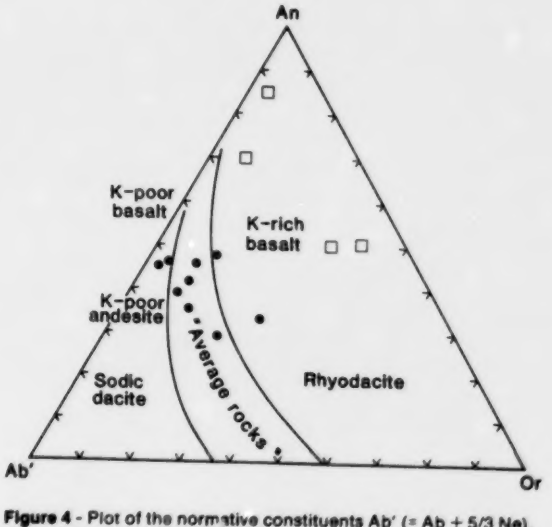

Figure 4 - Plot of the normative constituents Ab' (= Ab + 5/3 Ne), An and Or for the Combe Lake suite. Field boundaries are from Irvine and Baragar (1971). Symbols as for Fig. 3.

Table 1 - Chemical Compositions and CIPW Norms of Metavolcanic and Intrusive Rocks from the Combe Lake Area (Major Oxide Values are in Weight Percent; Trace Elements in Parts per Million).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	54.19	53.41	50.68	52.67	47.62	47.48	54.90	56.20	60.26	50.31	47.23	51.07	48.92	57.30
TiO_2	0.94	1.26	0.78	0.43	1.06	1.37	1.66	1.17	0.68	0.69	0.39	0.61	1.33	0.42
Al_2O_3	16.66	16.26	18.51	17.48	17.25	18.62	14.95	14.70	14.82	16.02	16.87	17.47	17.42	15.29
Fe_2O_3	5.51	1.93	2.47	2.74	8.80	7.65	3.50	3.17	5.11	2.67	2.36	3.25	9.81	2.62
FeO	6.64	10.30	6.71	6.75	3.61	7.59	8.10	10.79	5.65	7.88	7.67	6.53	4.32	5.80
MnO	0.29	0.21	0.15	0.17	0.17	0.19	0.18	0.28	0.16	0.19	0.17	0.17	0.21	0.22
MgO	5.41	6.29	5.67	5.71	3.10	3.44	3.05	2.11	3.26	7.72	12.25	5.56	2.31	5.46
CaO	6.13	5.49	9.15	9.74	15.14	6.82	6.31	4.91	4.99	9.99	9.88	11.02	10.25	7.14
Na_2O	3.66	3.25	4.34	2.94	0.65	0.61	2.53	3.31	0.82	2.43	1.44	3.34	3.72	3.62
K_2O	0.12	0.93	1.08	1.27	0.30	4.05	2.93	2.12	2.75	1.34	0.73	0.98	0.36	1.27
P_2O_5	0.40	0.45	0.22	0.18	0.42	0.46	0.71	0.41	0.16	0.17	0.20	0.19	0.57	0.17
LOI	0.10	0.57	0.68	1.02	1.89	3.13	0.88	0.32	1.40	0.89	2.53	1.41	0.47	0.75
Total	100.05	100.35	100.44	101.10	100.00	101.41	99.72	98.99	100.36	100.30	101.74	101.51	99.69	100.06
Rb	1.5	55	66	50	9	225	102	76	153	45	31	35	1.5	48
Sr	630	291	306	581	1401	169	109	389	160	306	308	488	1077	298
Y	33	30	24	26	31	37	54	53	39	29	22	18	16	40
Zr	167	145	80	116	91	188	237	126	151	64	49	55	219	154
Nb	10	11	11	10	7	14	28	22	10	20	11	9	8	12
Ba	201	715	315	366	232	1190	1237	415	998	376	252	327	615	388
V	115	153	99	189	245	166	131	15	114	196	111	217	173	82
Q	8.88	2.88		0.25	13.21	6.64	9.07	9.07	27.32					
C		0.92				1.84			1.73					
or	0.71	5.50	6.39	7.50	1.81	24.33	17.44	12.69	16.41	7.69	4.35	5.78	2.14	7.55
ab	31.15	27.54	30.90	24.84	5.59	5.25	21.63	28.38	7.01	20.68	12.28	28.22	31.67	30.84
an	27.20	24.53	27.88	30.71	44.01	31.64	21.08	17.86	24.19	29.01	37.70	29.74	29.95	21.84
ne			3.19											
wo					3.48								0.78	
di	0.81		13.46	13.62	16.95		5.33	3.71		16.26	18.48	19.57	12.49	10.54
hy	21.22	33.49		18.64		16.11	16.34	21.67	14.40	12.80	15.77	3.06		18.00
ol			13.32							5.59	17.61	8.20		
mt	7.22	1.55	2.77	3.14	10.21	10.33	4.13	3.34	6.79	2.93	2.54	2.91	11.86	3.11
il	1.80	2.40	1.48	0.82	2.04	2.64	3.22	2.25	1.69	1.32	0.75	0.97	2.54	0.80
hm					1.81								1.32	
ap	0.95	1.07	0.52	0.43	1.06	1.11	1.70	0.98	0.38	0.40	0.48	0.46	1.36	0.41

Ref. No.	Sample No.	Field Description	Geochemical Categorization
1	674S111	massive metavolcanic rock, light grey-green	andesite-basalt
2	674S197	massive metavolcanic rock, light grey-green	andesite-basalt diorite-gabbro
3	684S14	massive metadiorite	diorite
4	684W28	massive metadiorite-granodiorite	diorite
5	684S184	metavolcanic rock, epidotized and altered	basalt
6	694CS13	metapyroclastic rock, epidotized and altered	basalt
7	694G57	coarse grained metadiorite	diorite
8	694G14A	medium- to coarse-grained diorite-gabbro	diorite
9	694C515	pillowed metavolcanic rock	andesite
10	694C125	foliated metadiorite-amphibolite	diorite
11	694G91	coarse-grained metagabbro	diorite
12	694S111	coarse-grained metadiorite-granodiorite	diorite
13	694SG57	amphibolitic gneiss	basalt
14	694G100	medium-grained metadiorite	diorite

The Zr - Ti/100 - Sr/2 discrimination plot (Fig. 11) displays a clustering of points in the calc-alkaline field but with some 'scattering' along a linear trend towards and away from the Sr apex. It has been demonstrated by Smith and Smith (1976) that this pattern of scattering is a result of the mobility of Sr which may be enriched or depleted relative to Ti and Zr during metamorphism. Clearly, some of the Combe Lake samples have suffered Sr mobility during metamorphism. Significantly, those that were determined to be altered by consideration of the alkali concentrations (Fig. 3) also display the greatest scatter on this diagram and plot outside the basalt fields. The proposed migration of Sr does not, however, entirely invalidate the use of this diagram

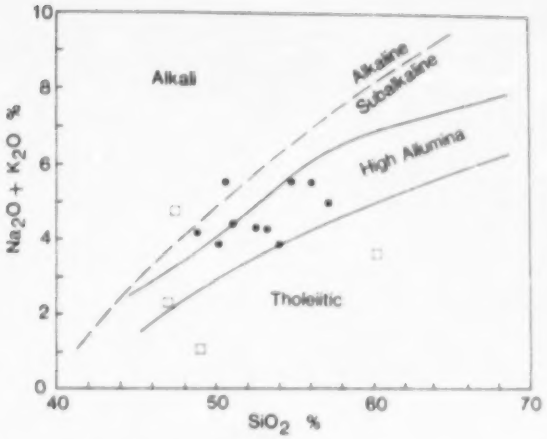

Figure 5 - Plot of total alkalis vs. silica for the Combe Lake suite. Boundaries separating the alkali, high alumina (calc-alkaline) and tholeiitic fields are from Kuno (1966); the boundary separating the alkaline and subalkaline fields is from Irvine and Baragar (1971). Symbols as for Fig. 3.

When plotted on an AFM diagram (Fig. 9), no trend is discernible but the 'unaltered' members of the suite fall mainly into the calc-alkaline field, with a few transitional varieties showing tholeiitic affinities.

The use of trace and minor element distributions, particularly of the immobile elements (e.g. Ti, P, Mn, Y, Zr and Nb), is now a well-established and successful technique for the characterization and determination of ancient geotectonic settings. Numerous plots using these elements have been suggested as a means of discriminating between basaltic rocks of different tectonic environments. One of the most widely used is the Zr - Ti/100 - Y.3 plot (Fig. 10) of Pearce and Cann (1973). The classification of the basaltic and basaltic-andesitic members of the Combe Lake suite according to this plot is in agreement with that suggested by the major and trace element relationships already discussed; although some scatter is apparent, the rocks display mainly calc-alkaline affinities, with some falling into the combined field for calc-alkaline, arc tholeiite and oceanic tholeiite basalts. Oceanic tholeiitic affinities can be ruled out on the basis of both major element composition and lithological associations.

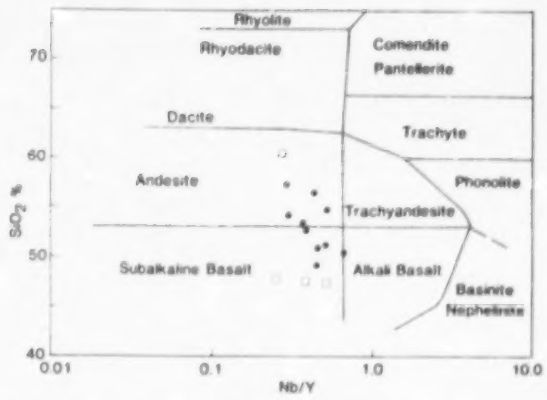

Figure 7 - Plot of Nb/Y vs. SiO_2 for the Combe Lake suite. Classification boundaries after Winchester and Floyd (1977). Symbols as for Fig. 3.

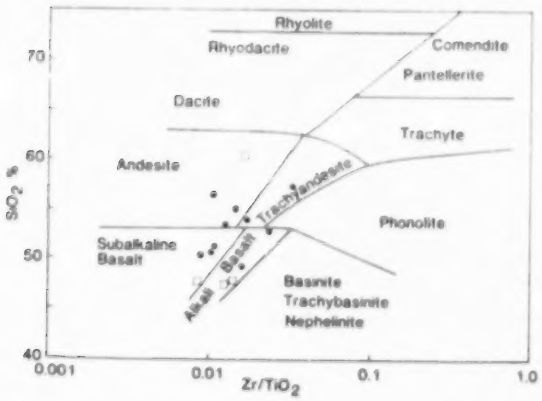

Figure 6 - Plot of Zr/TiO_2 vs. SiO_2 for the Combe Lake suite. Classification boundaries after Winchester and Floyd (1977). Symbols as for Fig. 3.

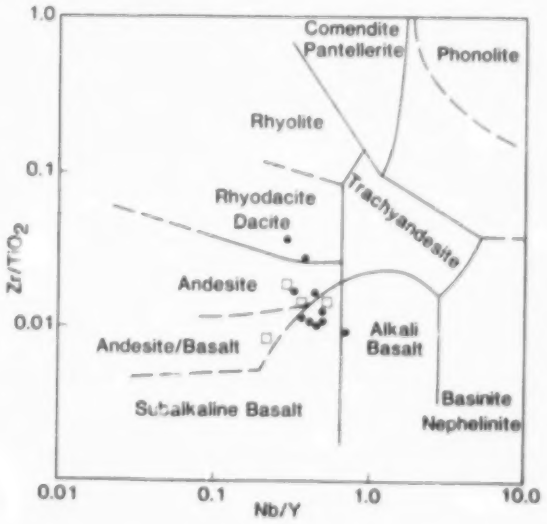

Figure 8 - Plot of Nb/Y vs. Zr/TiO_2 for the Combe Lake suite. Classification boundaries after Winchester and Floyd (1977). Symbols as for Fig. 3.

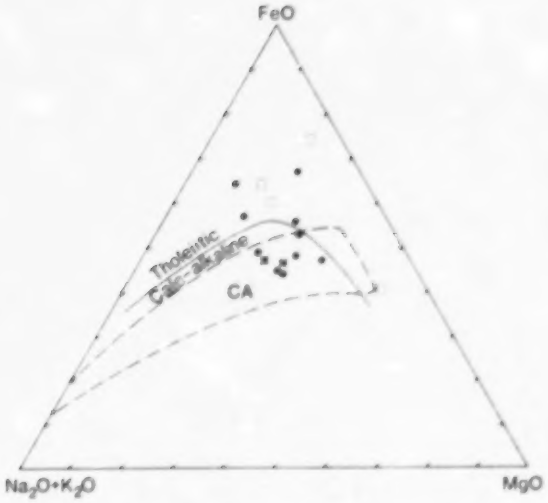

Figure 9 - AFM plot of the Combe Lake suite. Band CA represents the compositional trends of some typical calc-alkaline volcanic suites (i.e. Cascade, Aleutian and New Zealand provinces) after Ringwood (1975). The calc-alkaline:tholeiitic boundary (solid line) is from Irvine and Baragar (1971). Symbols as for Fig. 3. Average compositions of early plateau-forming basalts from Patagonia (Baker et al., 1981) are represented by crosses.

in this instance, since the trend of scattering is such that the affected samples would have fallen within or close to the calc-alkaline field prior to metamorphism.

Discussion

The chemical characteristics of the Combe Lake suite are mainly calc-alkaline to tholeiitic, possibly suggesting that the magmas were generated and emplaced in a subduction-related volcanic arc setting. According to the models of Ray and Wanless (1980) and Lewry et al. (1981), the metavolcanic and intrusive units in the Wollaston Domain, including those in the Courtenay-Cairns Lake belt, were generated and emplaced during the early stages of rifting of Archean continental crust. Modern examples of continental rift environments, such as the East African Rift System, range from highly alkaline to alkaline (in East Africa and Ethiopia), representing initial stages of rifting, through types transitional between alkaline and tholeiitic (the Afar region), to tholeiitic (in the Gulf of Aden and Red Sea), which represent advanced rifting and early sea-floor spreading (Pearce, in press).

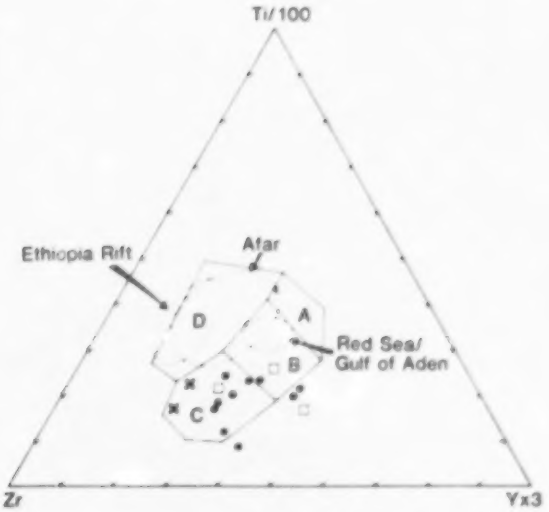

Figure 10 - Zr, Ti and Y discrimination plot for the Combe Lake suite. Symbols as for Fig. 3. 'Within-plate' (ocean island and continental) basalts plot in field D, ocean-floor basalts in field B, low-potassium tholeiites in fields A and B, calc-alkaline basalts in fields C and B. Field boundaries are from Pearce and Cann (1973). Also shown are the areas of distribution and basalts from rift environments, after Pearce (in press). Average compositions of early plateau-forming basalts from Patagonia (Baker et al., 1981) are represented by crosses.

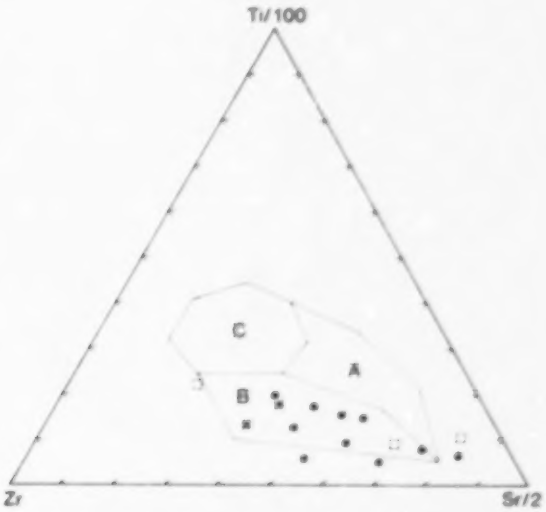

Figure 11 - Zr, Ti and Sr discrimination plot for the Combe Lake suite. Symbols as for Fig. 3. Ocean-floor basalts plot in field C, low-potassium tholeiites in field A and calc-alkaline in field B. Field boundaries are from Pearce and Cann (1973). Average compositions of early plateau-forming basalts from Patagonia (Baker et al., 1981) are represented by crosses.

Trace element characteristics of basalts from rift regions, when plotted on discrimination plots such as the Zr - Ti - Y diagram (Fig.

10) are transitional in that those from regimes of very early rifting (Ethiopian Rift) plot as 'within plate' (continental) basalts, whereas those from late rifting - early sea-floor spreading regimes (Gulf of Aden and Red Sea) plot as oceanic basalts; intermediate stages of rift development (the Afar) produce basalt suites that overlap both 'within plate' and oceanic fields (Pearce, in press).

Clearly, in terms of Zr, Ti and Y, the Combe Lake suite does not display characteristics analogous to continental rift basalts. Further, it is dominantly calc-alkaline in affinity and does not possess the major element characteristics expected from continental rift or oceanic basalts. Normatively, the Courtenay Lake rocks are dominantly hypersthene bearing (Table 1), consistent with a calc-alkaline or tholeiitic character. A single sample (684-S-14) contains nepheline and may be an alkali basalt.

Although the geochemical evidence strongly favours the Combe Lake suite being part of a volcanic arc, it may alternatively have been emplaced in a back arc environment, an interpretation that could perhaps be more easily accommodated by plate tectonic models for the Churchill province.

Baker et al. (1981) have described plateau basalts from the Senguerr and Morro Negro regions of Patagonia that have many characteristics similar to the Courtenay Lake suite. These include high Al_2O_3 and P_2O_5, and trace and major element distribution patterns on the AFM (Zr - Ti - Y and Zr - Ti - Sr) plots (Figs. 9, 10 and 11) that display dominantly calc-alkaline affinities. In many other respects (e.g. normatively) they also appear tholeiitic. One major difference between the suites concerns the TiO_2 content, which is higher in the Patagonian basalts.

Baker et al. (1981) suggest that "Patagonian volcanism may have developed in an extensional regime created as an indirect response to subduction and it may represent incipient crustal rifting in a type of back-arc environment". By analogy, the Courtenay Lake suite may have been emplaced in a similar environment.

Conclusions

1) Major and minor element geochemical data indicate that metavolcanic and intrusive rocks from the Courtenay Lake area are mainly basaltic to basaltic-andesite in composition and display dominantly calc-alkaline to lesser tholeiitic affinities.

2) General geochemical characteristics, together with the application of geotectonic discrimination techniques involving immoble minor and trace elements, suggest that the suite may have been emplaced in a volcanic arc environment.

3) An alternative interpretation of the data is that the suite was emplaced in a back arc environment subject to incipient crustal rifting indirectly related to subduction processes.

4) Although this study is of a preliminary nature, the data are sufficient to suggest that it may be necessary to modify existing plate tectonic models for the evolution of the Wollaston and Rottenstone - La Ronge Domains.

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ECONOMIC GEOLOGY INVESTIGATIONS

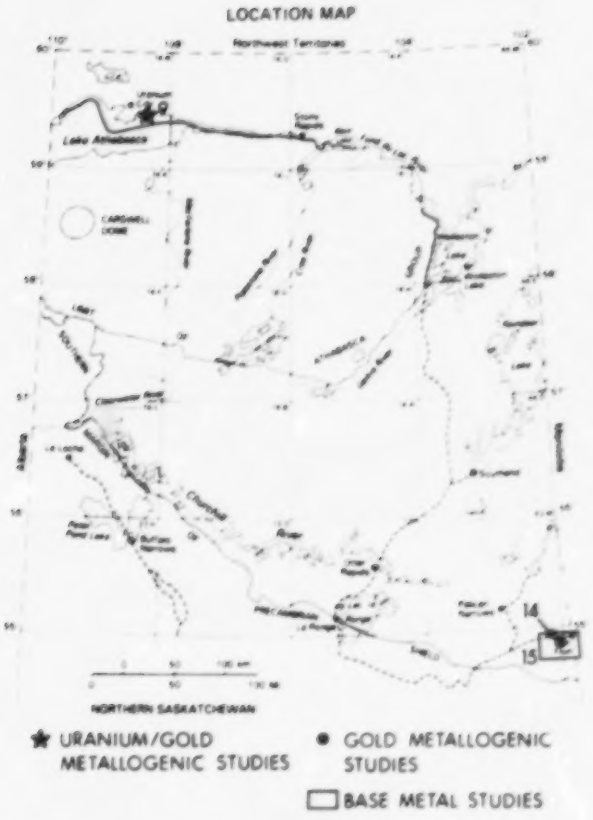


Figure 1 - Location of divisional[1] Economic Geology Projects reported here. Numbers on map refer to projects listed below.

Project No.	Area/Short Title	Project Leader(s)
Uranium/Gold Metallogenic Studies:		
8309	Nicholson Bay Area	T.I.I. Sibbald
Gold Metallogenic Studies:		
8214	Flin Flon - Amisk Lake Area	J.G. Pearson
Base Metal Studies:		
8215	Flin Flon Base Metals Project[2]	G.R. Parslow and J.W. Gaskarth

[1]Economic geology projects of other institutions not included unless directly funded.
[2]Contracted to the University of Regina

Introduction

by T. I. I. Sibbald

The Economic Geology Section undertook three field projects of which one was contracted to the University of Regina (Fig. 1). In addition office projects and the resident geologists' programs were maintained. The reduced level of field activities compared to 1982 reflects re-emphasis of the 1983-84 program toward primary geological mapping.

Uranium - Gold Metallogenic Studies

This project followed up on mapping carried out in the Nicholson Bay-Goldfields area in 1982 and involved field and geochemical studies. Ultramafic and associated rocks outcropping to the east of Nicholson Bay were re-examined and sampled for geochemical analysis. Preliminary results suggest the existance of three rock units approximating peridotite, pyroxenite and basalt in chemical composition and distinguished in the field as ultramafic, fine-grained mafic and medium-grained mafic rocks respectively. The ultramafic rocks are possibly of komatiitic affinity.

A small area north of MacKintosh Bay was also geologically mapped at 1:20,000 scale to complete coverage of the CSMA photomap sheet 6400-65900 of the Nicholson Bay-Goldfields area. The new work did not add significantly to geological interpretation of the area. Selected bedrock samples collected in 1982 were analyzed for a variety of elements including gold. Some weak gold anomalies were identified, the most significant of these occuring in a sulphide-rich zone underlying the Nicholson Bay ultramafic complex. Samples from pitchblende veins at Nicholson Bay, Fish Hook Bay and Murmac Bay were also analyzed and found to contain, in addition to uranium, a wide suite of elements including nickel, cobalt, copper, lead, zinc, silver, gold, molybdenum, chromium, beryllium, yttrium and vanadium.

Gold Metallogenic Studies

The Creighton resident geologist continued gold studies in the Flin Flon-Amisk Lake area through mapping and sampling of six gold prospects (V.M. occurrence, Graham Mine, Mosher Lake south, Wekach Lake, Lucky Strike and Gull Island) and through synthesis of this and previous work, so that a coherent picture of gold mineralization in the area has now emerged. Two groups of gold occurrences can be recognized, respectively in the Douglas-Phantom Lake and Amisk Lake areas. In the first group gold mineralization is structurally controlled within supracrustal and plutonic rocks in fractures ranging in age from early- to post-tectonic. By contrast the second group of occurrences in the Amisk Lake area, which is also structurally controlled, occurs only in supracrustal rocks and subvolcanic intrusions. Alteration is more extensive in the second group and, although quartz and carbonate veins are mobilized in places into later structures, most are clearly early to pre-tectonic. On this basis it is proposed that the Douglas-Phantom Lake mineralization may have been generated by metamorphic fluids, whereas that in the Amisk Lake occurrences formed from hydrothermal systems active during or shortly after volcanism.

Base Metal Studies

Under the Flin Flin base metals project contracted to the University of Regina some further bedrock sampling was undertaken in the Flin Flon area to obtain samples of late dykes. Most effort however has been spent in chemical analysis and data processing. Preliminary results suggest that the chemistry of the East Amisk Lake rocks is similar to that of mid-oceanic ridge basalts, whereas that of rocks from the Annabel Lake and Hamell Lake areas is characteristic of an island arc association.

Mineralized Core Collection

The mineralized core collection is housed primarily at the La Ronge Precambrian Geological Laboratory, although small storage facilities are also established in Creighton and Uranium City. Important recent additions to the collection are submissions by Canadian Occidental Petroleum Ltd. - Inco Metals Ltd. (McClean Lake) and Eldor Mines Ltd. (Rabbit Lake). Rock suites from several mineral prospects have also been assembled by the resident geologists to augment the core collection. The cooperation of companies who submitted material is gratefully acknowledged.

Mineral Deposits Index

Work continued in liaison with the Geodata Section on the Saskatchewan Mineral Deposits Index with updating and verification of manual and computer files and transfer of data to metric scale base maps. Computer programs were generated for plotting of mineral deposits maps at any scale by commodity.

Mineral Deposits Maps

A new project was initiated, in which a series of 1:250,000 scale mineral deposit maps will be generated to augment the compilation series bedrock geological maps currently being published. As presently envisaged, the mineral maps will provide details of location, metal association, development status and type of mineralization as well as references to all source records. The 1:250,000 geological maps will be used as a base for data presentation and marginal notes will develop metallogenic concepts.

Resident Geologists' Offices

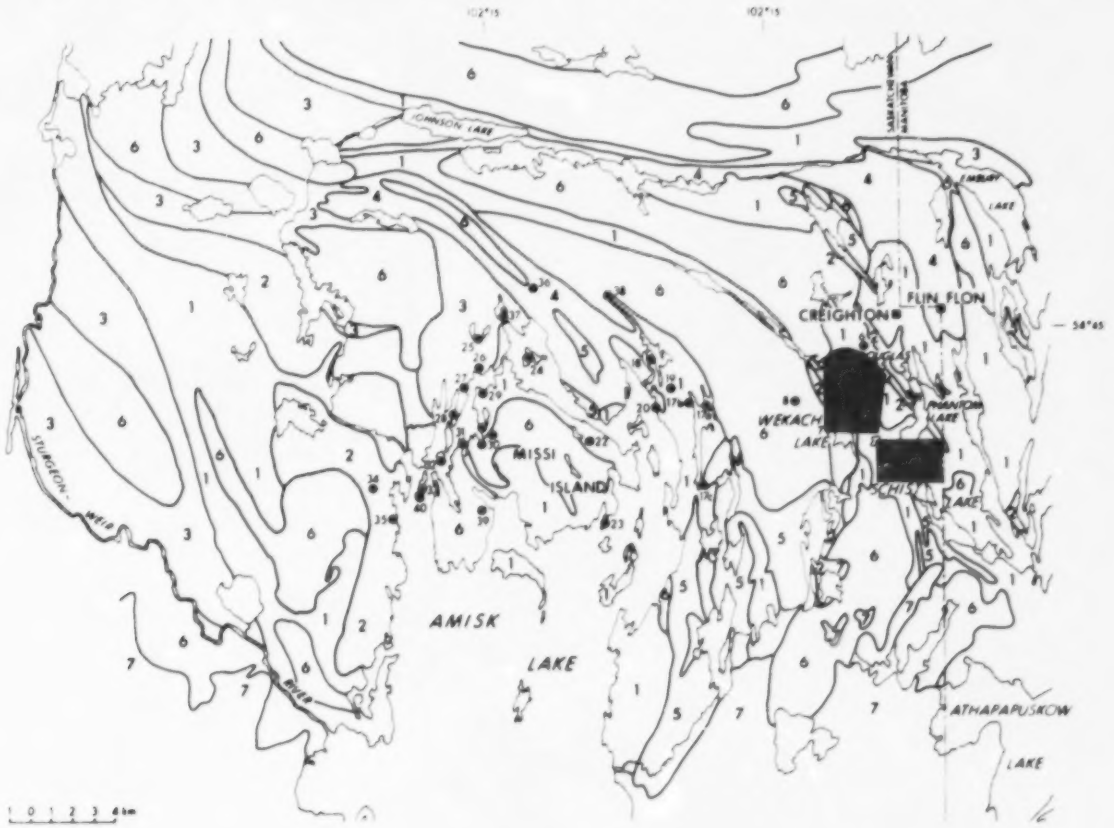
The resident geologists' offices in La Ronge, Creighton and Uranium City were reduced in number with the closure of the Uranium City office on September 15, 1983. The closure was in response to a much reduced level of exploration in the Athabasca Mining District and to the decreasing use of Uranium City, since termination of Eldorado Nuclear Ltd.'s Beaverlodge operation. Through the resident geologists and the staff of the Regina office the Economic Geology Section services the mining industry by providing up-to-date information on exploration and mining activities and opportunities in northern Saskatchewan. Numerous meetings with industry representatives were held during the year and several field visits undertaken. The resident geologists' offices continue to maintain files of current mineral claim maps, aerial photographs and assessment work submissions for their respective districts, and to sell geological maps and reports.

Project 8214

Gold Metallogenic Studies: Flin Flon-Amisk Lake Area

by J. G. Pearson

During the past five years, 31 of the 45 gold occurrences (Fig. 1) described in the published literature and/or assessment files have been examined. The close proximity of the gold deposits to one another in the Douglas Lake - Wekach Lake area and in the



LEGEND

3	Amisk Group – Epiclastics	7	Ordovician Dolomite
2	Amisk Group – Felsic Volcanics	6	Felsic Intrusives
1	Amisk Group – Mafic Volcanics	5	Mafic Intrusives
●	Gold Occurrence	4	Missi Group – Conglomerate and Greywacke
■	Areas Mapped in Detail		

Figure 1 - Geology and gold occurrences in the Flin Flon - Amisk Lake area. Shaded areas have been mapped in detail (see Figs. 2 and 3). 1, Newcor Mine; 2, Henning-Maloney Mine; 3, Rio; 4, Unity; 5, Cor; 6, Bomber Lake; 7, Wekach Lake; 8, Angelski; 9, Phantom Lake Mine; 10, MacMillan Mine; 11, North Phantom Lake; 12, Yellow Jacket Group; 13, Phantom-McRobbie Lake; 14, Dee Claims; 15, Boot Lake; 16, Dodo; 17a, Mosher Lake East; 17b, Mosher Lake North; 17c, Mosher Lake South; 18, Mitchell; 19, Sye; 20, Amisk Syndicate; 21, V.M. Group; 22, Derby (Hoodoo); 23, Lucky Strike; 24, Royal; 25, Kent; 26, Duplex; 27, Monarch Mine; 28, Amisk Gold Syndicate; 29, T.C.A.; 30, Laurel; 31, Beaver; 32, Hannay Island; 33, Waverly Island; 34, Wing; 35, Bud; 36, Graham Mine; 37, Golden Cross; 38, Robinson Creek; 39, Ace; 40, Sonora.

Phantom Lake - Schist Lake (West Arm) area allowed a detailed mapping program to be carried out in order to determine the geological setting of these deposits. In the Amisk Lake area, however, the gold deposits are more scattered and the geology is considerably more complex. Also, much of Amisk Lake has been mapped in some detail (Fox, 1976; McDougall et al., 1979), so that in the present study only the immediate area of each gold deposit was investigated. During the course of the investigations, samples were taken of both altered and unaltered rocks, as well as channel samples and grab samples from each of the occurrences visited.

Geological Setting

For the purpose of describing the gold deposits and their relationships to the evolution of the Flin Flon belt, deposits in the Douglas Lake - Wekach Lake (Fig. 2) and the Phantom Lake - Schist Lake (West Arm) areas (Fig. 3) can be considered separately from those around Amisk Lake. The stratigraphic relationship of the two areas is unclear. Volcanics in the vicinity of Douglas, Wekach, Phantom and Schist Lakes are entirely subaqueous and are tholeiitic in composition, whereas those in the Amisk Lake area vary from basalt to rhyolite in composition (Byers and Dahlstrom, 1954), and

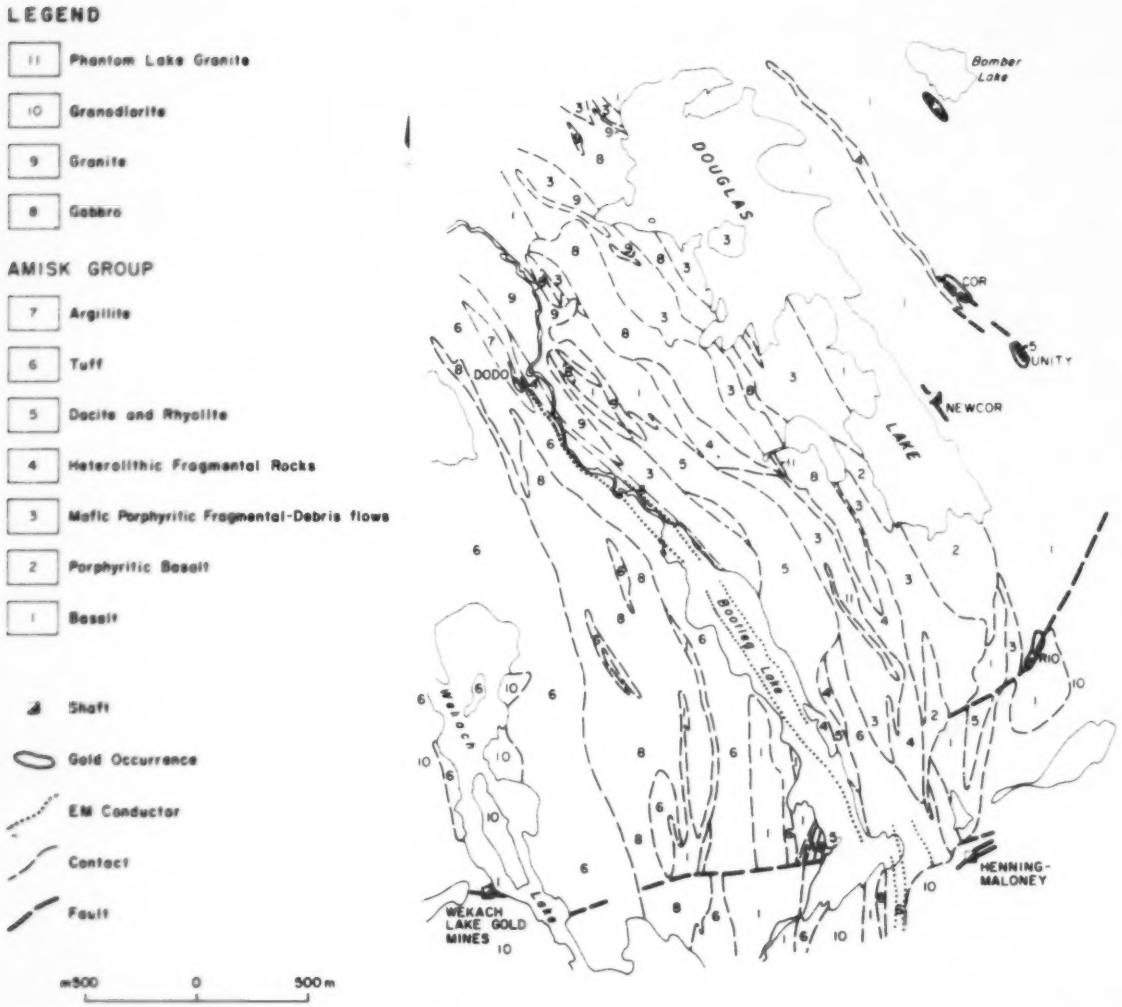


Figure 2 - Geology of the Douglas Lake - Wekach Lake area

evolve from subaqueous to subaerial to subaqueous (Van Wagoner and Van Wagoner, 1981), and from tholeiitic to calc-alkaline (Fox, 1976; Walker and Watters, 1982). This could mean that the rocks in the Amisk Lake area are at a higher stratigraphic level than those around Flin Flon or simply stratigraphically equivalent but at a higher level as evidenced by the subaerial paleotopographic features. Small, geochemically mature felsic edificies were built on the larger more primitive basaltic shield volcanoes. Similar evolutionary trends are noted by Bailes (1980) in the File Lake area of Manitoba.

Douglas Lake - Phantom Lake Area

Stratigraphy, Intrusion and Deformation

The Douglas Lake - Wekach Lake (Fig. 2) and the Phantom Lake - Schist Lake (West Arm) areas (Fig. 3) represent about the same stratigraphic level in the volcanic pile, separated by the Boot Lake and Phantom Lake plutons. A graphitic argillite conductor that extends through the West Arm of Schist Lake (and probably hosts the Hudson Bay Mining and Smelting Co. Ltd. West Arm Mine) is correlated with a conductor that extends through the central part of Bootleg Lake. In addition, the gross lithology above and below the conductor is similar (Fig. 4). Using the conductor as a stratigraphic marker, the stratigraphically lowest unit (exposed only in the Phantom Lake area) is a massive, quartz and/or feldspar phyric rhyolite which has several features indicating way-up to the southwest. This is overlain by a thick sequence of tholeiitic basalts, pillow lavas and flow breccias, as well as some monolithic mafic fragmental rocks containing scoriaceous fragments. Also within the tholeiitic unit are massive and pillowed flows of plagioclase and plagioclase-pyroxene phyric basalt. The exposed stratigraphy is capped by a sequence of massive to tuffaceous rhyolite, rhyolite fragmental rocks and thinly bedded mafic to intermediate tuff.

At Douglas Lake the tholeiitic unit is overlain by thick heterolithic breccias, commonly with a plagioclase-phyric matrix, and possibly representing debris flows or pyroclastic flow deposits. Intermediate to acid pillow lavas (probably dacite in composition) with very large pillows (up to 5 by 1.5 m) occur within this unit, which is capped by thin bands of rhyolite and/or coarse acid fragmentals (tuff breccia), overlain in turn by the graphitic argillite - massive sulphide marker horizon and a thick sequence of bedded, mafic to acid, water-laid tuffs.

The volcanic rocks are intruded by gabbroic bodies, some of which represent feeder dykes and others which may be much later (diabase dykes, R. MacQuarrie, pers. comm.) and by fine-grained granitic dykes and sills.

The Boot Lake Pluton, the Reynard Lake Pluton and the Phantom Lake Granite are the latest intrusive phases in the area; of these, the Phantom Lake Granite is the youngest.

Structurally these rocks comprise a northwesterly striking, westerly facing and dipping homoclinal sequence which is on the west limb of the Beaver Road anticline (Stockwell, 1960). According to Stauffer and Mukherjee (1971) the area has been subjected to three phases of deformation (P_1, P_2 and P_3).

There are a number of northwesterly trending strike-slip faults with an unknown (probably small) amount of movement which were probably active through P_1 and possibly into P_2 time. The major fault is the east- to northeasterly-trending Rio Fault which was probably active into post-P_3 time. It has at least a 300 m of sinistral movement and probably also a significant vertical component. It is these fracture systems which appear to control the sites of gold mineralization.

Gold Mineralization

Two generations of gold mineralization are present in the Douglas Lake and Phantom Lake areas, respectively predating and postdating intrusion of the Phantom Lake Granite.

The early phase of mineralization includes the Newcor, Cor, Unity and Bomber Lake quartz-sulphide veins east of Douglas Lake. These veins are up to 1 m wide and occupy northwesterly trending P_1 or P_2 fractures. The veins consist of varying proportions of massive white to grey quartz, vuggy quartz and quartz breccia. The dominant sulphides are pyrite, arsenopyrite, chalcopyrite and sphalerite, present in different proportions in each of the veins. In the Cor occurrence both quartz and sulphides are zoned, with massive grey quartz and arsenopyrite at the vein margins and vuggy white quartz, pyrite and chalcopyrite at the vein centre.

The alteration zone around the veins is narrow and comprises silicification and possibly some potassic alteration. Friable yellow and red schistose rocks, probably consisting of jarosite (Sabina, 1971) alteration from the weathering of the sulphides, occur immediately adjacent to the veins.

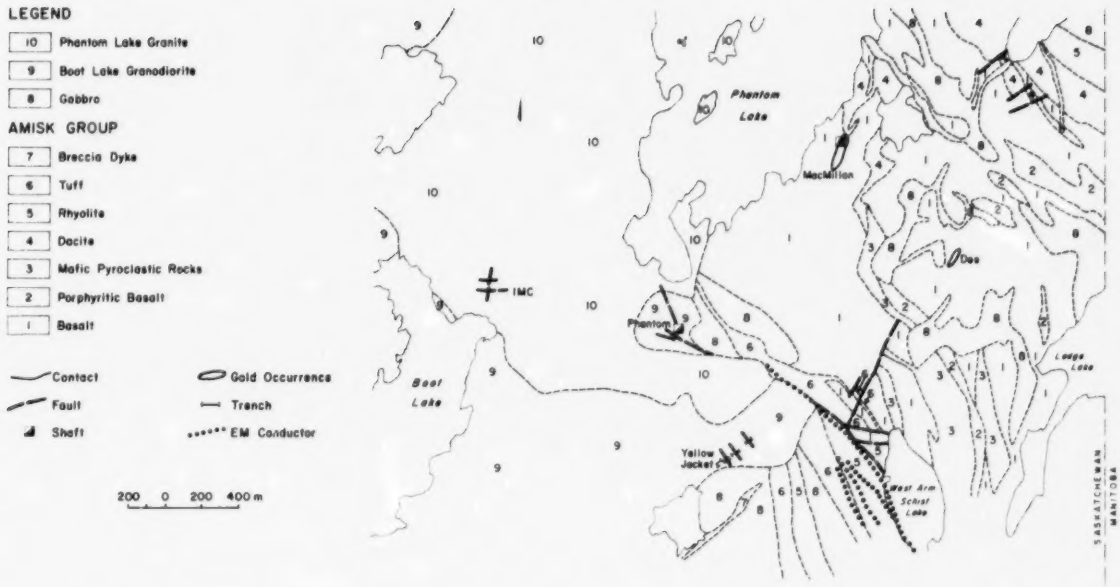


Figure 3 - Geology of the Phantom Lake - Schist Lake (West Arm) area.

Gold content of the veins ranges up to 60 g/t. Gold is largely submicroscopic and associated with in the sulphides, although in some polished sections it occurs as tiny discrete blebs within arsenopyrite grains.

The character and mineralogy of the second generation of gold mineralization appears to be a function of host rock composition plus other factors (i.e. amount and type of ground preparation). The two main types of mineralization include quartz veining along dilatant zones, particularly in plutonic rocks, and quartz-carbonate replacement zones and associated quartz veining along fractures in volcanic rocks.

The quartz vein type of mineralization includes that at the Henning-Maloney Mine, the Phantom Lake Mine and the Yellow Jacket occurrence in the Boot Lake Pluton, the IMC occurrences in the Phantom Lake Granite and the Wekach Lake Gold Mines occurrence in volcanic and volcaniclastic rocks. The Henning-Maloney Mine is in a dense, grey, very fine grained quartz vein hosted in diorite, a border phase of the Boot Lake Pluton. According to Byers et al. (1954), a shear zone parallels the hanging wall of a fine-grained basic dyke and several mineralized quartz veins (0.22 to 1 m wide) are developed on both sides of the dyke. Mineralization consists of sparsely disseminated pyrite, chalcopyrite and gold. The Phantom Lake Mine lies near the edge of the granodiorite pluton in a heterogeneous and deformed part of the pluton. Mineralization occurs in a northwesterly-trending, east-dipping fracture zone which contains discontinuous quartz stringers and veins with pyrite and chalcopyrite. Gold values are erratic although spectacularly high values are reported locally.

The Yellow Jacket occurrence south of Phantom Lake is hosted by diorite and granodiorite which have been sheared and altered along easterly and northerly trending fractures. The mineralization is characterized by abundant fine-grained disseminated pyrite, and locally by carbonate and quartz veining, fuchsite and galena. Host rocks are sometimes altered to a red colour (hematite?) but also may be intensely bleached. The gold content in trenches varies up to 12 g/t. The IMC occurrence east of Boot Lake is contained within east- and north-trending fracture zones in the Phantom Lake Granite. In these zones the rock is bleached, in part rusty and cut by narrow (3 to 5 cm wide) quartz veins. The fractures contain chlorite, carbonate and possibly clay minerals. Pyrite and chalcopyrite are disseminated through the fracture zones.

The Wekach Lake Gold Mines occurrence is similar to the above vein-type deposits, and is probably located on the Rio Fault or one of its splays. The host rocks are basalt and

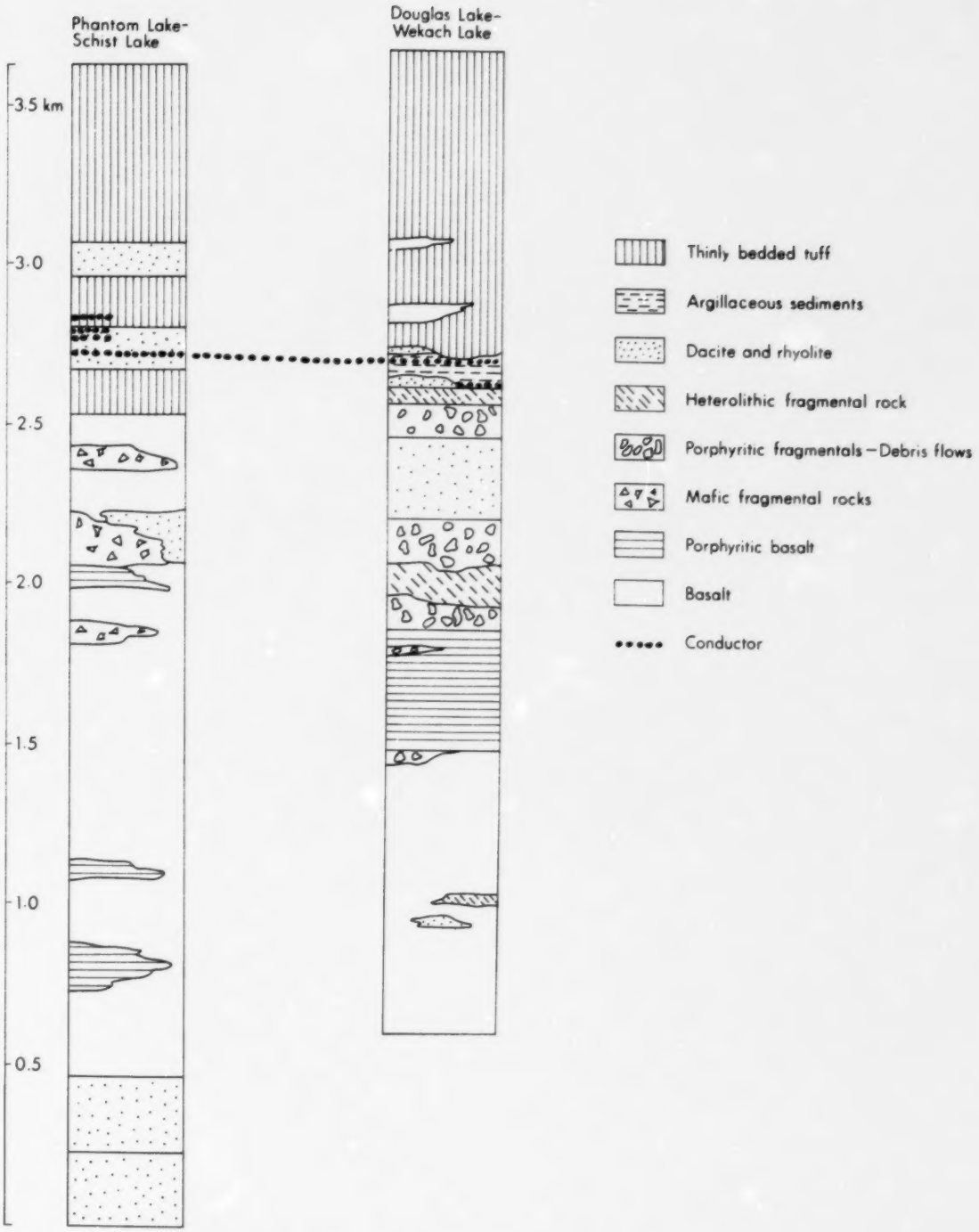


Figure 4 - Generalized stratigraphic sections for (a) the Phantom Lake - Schist Lake (West Arm) area and (b) the Douglas Lake -Wekach Lake area. The graphitic argillite conductor is considered to be a stratigraphic marker.

thinly bedded volcaniclastics or tuffs. They are cut by a 5 m wide shear zone containing lensoidal quartz-carbonate veins with small amounts of gold, pyrite and chalcopyrite. Veining developed early in the history of the fault, as the quartz veins are brecciated, displaced and drag-folded.

The MacMillan Mine, Dee occurrence and Rio zone comprise chert-like quartz-carbonate bodies with associated quartz veining. At the MacMillan Mine and Dee occurrence, the mineralized zones are conformable with the local stratigraphy. Massive homogeneous chert, containing scattered rounded blebs of carbonate and clinozoisite, flanks the quartz vein and appears to be of alteration origin. Mineralization, which includes gold, pyrite, chalcopyrite, sphalerite and galena, is associated with the quartz veining. At the Rio zone the silicified zone is discordant, occupying part of the Rio Fault, and contains ghosts of diorite, Phantom Lake Granite and basalt. Gold is found as very fine grained blebs within finely disseminated pyrite and at pyrite boundaries, and as discrete grains associated with pyrite. High gold values are obtained from coarse pyrite adjacent to northerly-trending quartz veins (P. Master, pers. comm.).

Amisk Lake Area

Stratigraphy, Intrusion and Deformation

The Amisk Lake area (Fig. 1), is underlain by a thick sequence of submarine tholeiitic basalts in the east which give way upwards to subaerial lava flows, debris flows and fragmentals, and finally to submarine intermediate calc-alkaline flows and fragmentals on the west side of Amisk Lake. A northerly-thickening wedge of turbidite sediments is present on the west side of the lake. Missi Island is intruded by a number of porphyritic subvolcanic bodies which range in composition from andesite to rhyolite and from part of a vent complex (Fox, 1976; Chute and Ayers, 1977). These rocks have extrusive equivalents in the West Channel area. The Missi Group of fluviatile sandstone and conglomerate was laid down following the cessation of volcanism.

The Amisk Lake area has been subjected to at least two periods of folding. The early phase was accompanied by development of major faults including the West Channel and Comeback Bay Faults. These faults, particularly the West Channel Fault, have several splays which occupy bays on Missi Island and the mainland. They were probably active during and after volcanism.

Gold Mineralization

In the Amisk Lake area gold is found in quartz veins and in pyritic fracture systems.

Gold-quartz veins lie in or near the boundaries of shear zones. Some, as at the Duplex and Golden Cross occurrences (Pearson, 1980), are irregular and sigmoidally shaped, and fill tension gashes at acute angles to the strike of the major fractures. Quartz veins at the Graham No. 3 occurrence (Fig. 5) and possibly also the Robinson Creek quartz zone (Pearson, 1982) may be at or near the crests of folds. However, the majority of occurrences (Monarch, Sonora, Mitchell, Mosher Lake) are conformable with nearby shear zones. The veins vary in width from a few centimetres to 5 m and range up to 100 m in strike length. Alteration associated with this veining includes carbonatization, silicification, sericitization and, less commonly, tourmalinization. The wall rocks commonly contain pyrite and arsenopyrite. Ore minerals present in varying proportions in the veins are pyrite, chalcopyrite, arsenopyrite, molybdenite and gold.

Auriferous sulphide-rich shear zones represent the other main type of gold occurrence in the West Channel area of Amisk Lake. They vary from narrow, fissile pyrite- and/or arsenopyrite-rich zones in upper Amisk Group sedimentary rocks (e.g. Waverly Island, Amisk Gold Syndicate (Pearson, 1980) and Gull Island West) to wider zones of disseminated pyrite mineralization in Missi Island dyke suite rocks and their extrusive equivalents (e.g. Laurel, Beaver (Pearson, 1980) and Gull Island West occurrences). The host rocks show clear evidence of cataclastic deformation, with volcanic and volcaniclastic rocks most strongly affected and altered to fissile carbonatized schists. By contrast, the dyke suite rocks display brittle deformation features, are variably altered and locally appear to have been brecciated with little movement. Fractures between the breccia fragments are filled with pyrite, chalcopyrite, chlorite, magnetite and carbonate. At the south Beaver occurrence, the mineralization consists of pyrite-magnetite veins in fractured quartz-feldspar porphyry. Euhedral magnetite crystals partially altered to hematite are also disseminated through the rock. At the other Beaver occurrences, the Laurel A and C occurrences and the Gull Island West occurrences, quartz-feldspar porphyry is intensely carbonatized and sericitized, in part to a yellow, friable, sandy rock. Up to 10 percent pyrite, chalcopyrite and/or sphalerite is disseminated through the rock. Arsenic, lead, zinc and copper are also

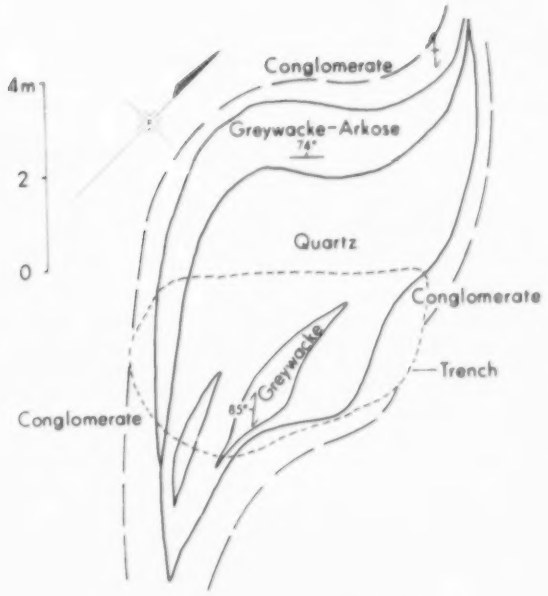


Figure 5 - Geological sketch map of the Graham No. 3 occurrence.

sporadically enriched. A gold-rich 'alteration halo' of 15 to 200 ppb Au is developed over an area of up to 1 km from these zones.

The Gull Island East occurrence comprises coarse quartz porphyry fragmentals containing disseminated pyrite, lenses of sphalerite and fuchsite, and anomalous gold values. The fuchsite-sphalerite lenses are folded on the second fold axial planes. McDougall and Walker (pers. comm.) indicate that the mineralized horizon continues to the north onto Missi Island. Alteration is apparently stratabound within the fragmentals, which are overlain by a fine-grained chloritic mafic rock (mafic tuff?).

Discussion

In the Douglas Lake area, the early quartz-sulphide veins occupy P_1 or P_2 fractures and predate intrusion of the major intermediate and felsic plutons. The vuggy nature of the veins and features such as comb texture indicate that these veins were introduced at a rather shallow depth, probably less than 4000 m (Boyle, 1979). The brecciated nature of the quartz vein at the Unity occurrence indicates that it was emplaced along an intermittently active fracture.

The other types of gold occurrences occupy fractures that formed in P_3 and post-P_3 time, after intrusion of the Phantom Lake Granite, which is the youngest intrusive rock in the Flin Flon area and is itself mineralized. The variation in the character of this group of gold occurrences appears related to the nature of the deposition site. For example, the Phantom Lake Mine quartz veins are suggestive of open-space fracture-filling, whereas the Rio zone occupies a wide brecciated fault zone in which mineralizing fluids altered gouge and rock fragments to a fine-grained chert-carbonate rock. The larger rock fragments in the zone show incomplete alteration and assimilation.

Gold mineralization in the Amisk Lake area contrasts with that observed near Flin Flon. All of the occurrences are in supracrustal rocks or subvolcanic intrusives; none are in P_2 granitoid plutons. Also, gold mineralization is present in both Amisk and Missi Group rocks, indicating that primary mineralization took place during or shortly after volcanism.

Alteration is much more widespread and distinctive than at Flin Flon and includes carbonatization, silicification, sericitization and tourmalinization. It appears to be structurally rather than stratigraphically controlled, except 1) at the Gull Island east occurrence, where alteration is confined in a coarse quartz porphyry fragmental unit and 2) at the Robinson Creek quartz zone, where alteration and veining are concentrated in a greywacke unit and not in the surrounding plutonic rocks or conglomerate (Pearson, 1982).

At the Robinson Creek and Gull Island east occurrences, the lenses of fuchsite and sphalerite are folded by the second fold event, as are mineralized quartz veinlets at Robinson Creek. There is also some remobilization of quartz and quartz-carbonate veins into the axial planes of these folds. Quartz veins in fracture zones in both the Amisk volcanics and sediments and the Missi sediments indicate that these fractures were active during and shortly after volcanism but were not active during the intrusion of the P_2 plutons.

From these lithologic, alteration and structural features, it is apparent that the gold mineralization in the Amisk Lake area is volcanogenic in origin. The intense carbonate alteration along fractures and the apparent lack of carbonate and oxide facies exhalites indicate that hydrothermal fluids used these fractures and other zones of

porosity as conduits to surface, but boiled before reaching the surface. The wide haloes of anomalous gold concentration indicate that mineralizing fluids percolated along many microfractures in the more brittle rocks in the area.

The differences in age, host rock, degree of alteration and style of mineralization indicate a fundamental difference in the formation of gold deposits in the Douglas - Phantom Lake and Amisk Lake areas. The later age of many of the gold deposits in the former area suggests that the deposits may have been generated from metamorphic fluids at the greenschist-amphibolite transition (Kerrich and Fryer, 1981; Kerrich and Hodder, 1982). In the Amisk Lake area, however, the extensive carbonate-sericite-silica alteration in a near-surface environment is more indicative of a precious metal hydrothermal system, similar to that envisaged by Pyon and Crocket (1982), which was active during or shortly after volcanism.

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Project 8309

Uranium-Gold Metallogenic Studies: Nicholson Bay Ultramafic Complex

by T. I. I. Sibbald, P. L. Schwann[1] and Colin E. Dunn

Alcock's (1936) geological map of the Goldfields area identifies gabbro, peridotite and amphibolite as a discrete lithological subdivision. Reference is made in his accompanying report to dark basic rocks, on the east side of Cornwall Bay, which are in part serpentinized (Alcock, 1936, p. 19). However, in later work by Christie (1953) there is no mention of ultramafic rocks, except in the legend to a geological sketch map of the Fish-hook Bay area, after Eldorado Mining and Refining 1944 Limited (Christie, 1953, Fig. 11).

Re-investigation of the Nicholson Bay area by the Saskatchewan Geological Survey (Sibbald, 1982) distinguished three main areas of ultramafic outcrop, respectively to the east of Nicholson Bay, in Fish-hook Bay and northwest of Cornwall Bay. In 1983 a program of geochemical bedrock sampling and mapping of the Nicholson Bay ultramafic was undertaken by Schwann and a biogeochemical study across this body for gold and platinum was carried out by Dunn (this volume). The present report describes some of the preliminary results of the bedrock sampling and mapping, and also documents trace metal data for samples collected from the ultramafic and underlying rocks.

General Geology

The ultramafics are contained within a supracrustal sequence metamorphosed to lower to middle amphibolite facies grade. The sequence comprises a wide variety of rock types among which quartzites, calcareous rocks and amphibolites predominate in proximity to the ultramafics. Pelitic schists, meta-arkoses, iron formations and mixed supracrustal units are also represented in the succession, which is intruded and/or metasomatically replaced by one or more phases of granite. Granite pegmatite dykes cut the granite bodies and the supracrustals, and contain tourmaline and beryl. These basement rocks are overlain successively by unmetamorphosed clastic sediments of the Martin Group to the northwest of Nicholson Bay, and by presumed Athabasca Group sandstone and basal breccia on the west side of the bay (Sibbald, 1982). Post-metamorphic lamprophyre and diabase dykes cut the basement rocks, but bear an uncertain relationship to the overlying clastic sequences.

The age of the basement supracrustals is presently unknown, although Rb-Sr dating of the granitic rocks has yielded an isochron age of 2155±40 Ma for the Box Mine granite and a Rb-Sr model age of 2050 Ma for the Athona granite (Bell and Blenkinsop, 1982). Sibbald and Lewry (1980) have argued in favour of an Aphebian age for the supracrustals in contrast to the Archean age proposed by Tremblay (1972) for the correlative Murmac Bay Formation exposed in the Beaverlodge area to the north.

Several gold and uranium occurrences including one past producing gold mine and two small uranium producers are located in the vicinity of Nicholson Bay. Gold is typically found in granitic rocks, predominantly in quartz veins, both as free gold in association with pyrite, galena, sphalerite and chalcopyrite, as at the Athona property, and as gold in pyrite as at the Box Mine. Gold also occurs in pitchblende veins of complex mineralogy and geochemistry; for example, at Nicholson Bay and Fish-hook Bay. Uranium and gold are associated with cobalt, nickel, arsenic, copper, vanadium, lead and platinum (Christie, 1953; Robinson, 1955). Uranium-gold mineralization is characteristic of some Athabasca Basin unconformity type deposits which are also mineralogically and geochemically complex. This apparent similarity together with observed field relationships (Sibbald, 1982) suggests that the uranium-gold veins may be of unconformity type and thence that the gold mineralization in the granites is older. In respect to the granite mineralization, the metasomatic replacement character of the auriferous granites in general and the high initial $^{87}Sr/^{86}Sr$ ratio of the Box granite in particular suggests derivation of the granites, and presumably the contained gold, from an older crustal source.

A variety of supracrustal rocks can be envisaged as potential sources for the

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mineralization including mafic (amphibolitic) and ultramafic rocks, representing possible volcanics, intercalated sediments which include iron formation as well as quartzites and quartz pebble conglomerates (paleoplacers).

Geology of the Ultramafic Complex

The Nicholson Bay ultramafic complex (Fig. 1) occupies an area approximately 0.5 km wide and 1.25 km long and comprises ultramafic and subordinate mafic components. It is surrounded by metasediments. As serpentinization of the ultramafics has masked any primary textures, it is not certain whether these rocks are intrusive or extrusive. Detailed mapping of the Fish-hook Bay ultramafic body by Eldorado Nuclear Ltd. (Jones and Fleming, 1968) suggests a discordant intrusive relationship between this sheet-like body and the adjacent supracrustals. The following subdivision of lithologies is preliminary and may require modification after completion of geochemical studies.

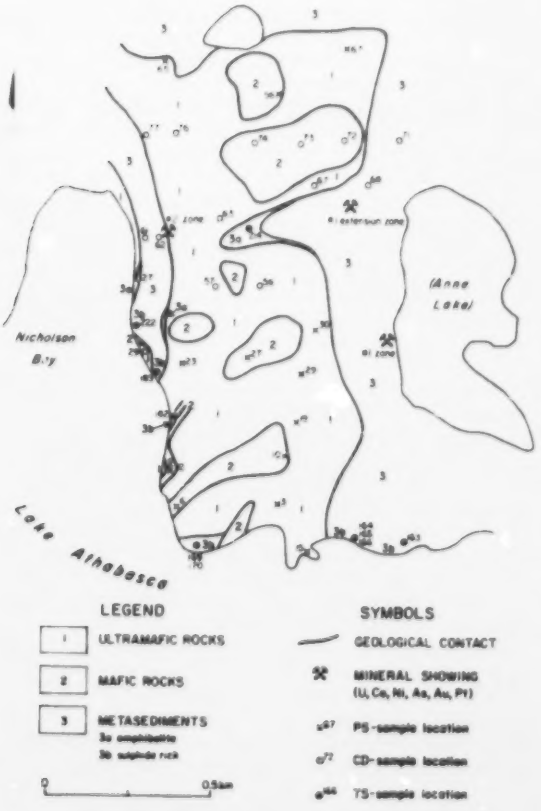

Figure 1 - Geological sketch map and sample location map, Nicholson Bay ultramafic complex.

The ultramafic rocks are distinguished by their unusual weathering characteristics. Outcrops are orange-brown in colour and exhibit a rectangular pattern of intersecting serpentine veins on weathered surfaces. These veins are from 1 to 5 mm in width, fine-grained and fibrous, but weather steel-grey to blue and are less resistant than their surroundings. On fresh surfaces the veins are dark coloured, and are seen to incorporate pods of the ultramafic rocks which have been altered to pale green amphibole. In some areas the veining texture is subordinate to 'mottling' in which small, dark, fine-grained patches of serpentine randomly replace the original ultramafic rock. On the southwestern end of the ultramafic outcrop, serpentine appears to have preferentially replaced small (0.5 to 2.0 mm) crystals, possibly of olivine, producing a spotted appearance.

In hand specimen the mineralogy is indistinct. Microscopically, the following minerals have been identified: serpentine, anthophyllite and relict pyroxene. Disseminated pyrite and hematite veins are present locally.

Mafic rocks are subordinate to the ultramafics and are represented by fine- and medium-grained types. The fine-grained mafic rocks are brown weathering, dark green on fresh surfaces, fine- to medium-grained and of indistinct mineralogy in hand specimen. In one locality they contain elongate dolomite amygdules 1 to 4 mm in length. Disseminated pyrite is commonly present.

Crosscutting mafic dykes of similar appearance are present at the southwestern end of the ultramafic outcrop, and intrude the sedimentary sequence.

Medium-grained mafic rocks occur in several locations and consistently form topographic highs. They are light orange-brown weathering, dark green to blue-grey when fresh and composed essentially of green amphibole and subordinate white feldspar. A little pyrite is typically also present.

The metasediments comprise mica (talc?) schists, amphibilites, quartzites, calcareous-quartzites, calc-silicate rock and minor carbonates. The mica (talc?) schists outcrop on the shore of Nicholson Bay as a 1 m-thick layer on the western side of the ultramafic body. They appear to be composed primarily of white mica (talc?) and quartz. A massive commonly pyritic amphibolite is

closely associated with the mica schists, occurring as pods within the schist and as a discrete layer up to a few metres thick over a distance of some 50 m in this location. This lithology has been identified at other points along the ultramafic-supracrustal contact. It is usually rusty weathering because of contained sulphides and shows a distinctive texture of radiating fibrous amphiboles forming bow-tie structures up to 3 cm in length set in a quartzose matrix. Calcareous quartzites, calc-silicates and minor carbonates surround the ultramafic complex and bound its western, eastern and northern sides. As the three rock types are irregularly intermixed, subdivision into large scale units is somewhat arbitrary. The calcareous quartzites are typically white massive units comprised essentially of quartz and pale green diopside. Diopside occurs scattered through the rock as discrete crystals or forming coarsely crystalline pale green diopsidite layers and pods. Dolomite pods are developed locally and typically rimmed by coarse diopsidite 'skarn'. The calc-silicates comprise massive pale green diopsidites of coarse to pegmatitic grain size. They typically weather brown and give rise to a distinctive hummocky terrain. Dolomitic carbonates occur as buff weathering massive units, layers and pods formed by medium-grained, white dolomite and minor calc-silicate minerals.

In the immediate proximity of the ultramafic body the metasediments are rich in iron sulphides and gossanous. Sulphides are typically disseminated throughout bedrock, but also form irregular quartz-sulphide zones typified by rusty pyrite set in a vuggy quartz matrix. In places the pyrite and quartz are interlayered. Hematization and other alterations of bedrock are locally important, particularly in the vicinity of fracture-controlled pitchblende vein occurrences (Nicholson Nos. 1, 1 extension and 2 zones) (Fig. 1).

Structure

The ultramafic complex and the surrounding metasediments exhibit little structure. The rocks of the ultramafic complex lack small-scale layering, and schistosity is generally not apparent except in localized (shear) zones at the margins of the complex, or internally at contacts of the ultramafic and mafic rocks. In harmony with regional structural trends, most strikes are northerly

Table 1 - Whole-rock and Trace Element Analyses[1], Ultramafic Complex, Nicholson Bay Area

Sample No.	SiO_2[2]	Al_2O_3	Fe_2O_3[3]	CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	LOI[4]	Ni	Co	Cr	V	Zr	Y
Ultramafic rocks:																	
PS3	41.0	4.0	9.8	3.7	28.8	<.01	.15	.19	.08	.03	12.1	1680	85	1588	85	24	5
PS15	45.2	4.4	7.7	0.9	30.4	<.01	.45	.23	.15	.02	10.1	1950	68	1931	86	42	8
PS19	44.0	4.4	10.2	0.3	30.4	<.01	.36	.22	.12	.02	9.8	1984	93	1996	91	40	1
PS23	44.7	4.1	11.2	0.9	27.8	<.01	.20	.20	.13	.02	10.1	1723	97	4306	89	25	4
PS29	41.8	2.9	9.7	1.0	31.6	<.01	.23	.15	.12	.02	11.8	2156	93	3560	63	28	3
PS30	38.6	3.6	10.0	0.9	32.9	<.01	.21	.11	.09	.02	12.9	1900	123	3500	56	29	1
PS65	45.0	4.0	12.0	1.4	27.2	<.01	.24	.21	.21	.01	9.4	1830	95	1682	81	34	7
PS67	42.7	3.8	7.4	0.3	33.0	<.01	.18	.17	.11	.02	11.9	2230	90	1262	47	34	3
CD29	ND	5.7	13.4	2.4	26.0	<.01	.39	.32	.09	.02	ND	1795	116	2835	123	8	3
CD56	ND	4.9	12.1	2.2	32.2	<.01	.44	.25	.17	.03	ND	2071	88	2088	92	10	2
CD57	ND	3.8	9.2	2.1	29.1	<.01	.33	.20	.16	.03	ND	2240	62	2203	82	10	4
CD63	ND	3.3	9.8	9.3	26.4	<.01	.29	.05	.12	.02	ND	490	53	888	40	27	6
CD67	ND	3.2	9.9	3.8	32.4	<.01	.37	.15	.19	.03	ND	2267	105	2281	74	22	5
CD76	ND	0.1	9.4	5.2	26.8	.03	.63	.44	.14	.02	ND	1436	72	2401	106	31	4
CD77	ND	4.1	7.1	0.4	31.0	.03	.35	.20	.08	.02	ND	2412	101	2200	74	16	2
X	42.9	4.3	9.9	1.8[5]	29.7	<.01	.32	.20	.13	.02	11.0						
Fine-grained mafic rocks:																	
PS6	50.8	4.8	7.4	11.8	18.5	.04	.50	.27	.18	.01	5.5	156	48	1939	174	24	5
PS12	51.2	5.6	9.5	9.0	18.8	.16	.57	.38	.15	.02	4.5	155	49	834	218	28	2
PS27	48.2	7.3	9.5	6.2	23.0	<.01	.30	.38	.15	.04	4.6	571	61	1471	131	40	3
X	50.7	5.9	8.8	9.0	20.1	.07	.46	.33	.16	.02	4.9						
Medium-grained mafic rocks:																	
PS10	51.5	15.0	12.8	6.1	7.6	1.0	4.0	.84	.14	.05	0.9	63	46	68	230	69	12
PS56	51.0	16.0	10.6	8.1	7.6	0.7	3.6	.87	.15	.05	1.3	84	49	62	224	51	16
CD72	ND	16.3	12.8	4.2	11.6	1.9	3.1	1.05	.18	.11	ND	70	44	78	228	64	20
CD73	ND	16.1	9.2	9.4	6.5	1.6	3.4	.77	.08	.08	ND	113	44	168	186	22	10
CD74	ND	15.0	9.1	6.1	11.8	2.6	2.1	.65	.15	.04	ND	162	31	376	178	32	8
X	51.3	15.7	10.9	6.8	9.0	1.6	3.2	.84	.14	.07	1.1						

[1] $HF/HNO_3/HClO_4$ digestion; major elements plus Ni and Pb by atomic absorption; Au by MIBK extraction and atomic absorption; all other elements by inductively coupled argon plasma spectrometry.
[2] SiO_2 is an estimate, determined by addition of all major oxides, minor elements and LOI, and attributing the balance (i.e. to 100 percent) to silica. Silica cannot be calculated in the samples prefixed CD because LOI data are not available.
[3] Total iron is expressed as Fe_2O_3.
[4] Loss-on-ignition at 900°C (mainly structural water plus some CO_2).
[5] Sample CD-63 omitted; by including that sample the mean increases to 2.3.
ND = not determined.

Table 2 - Whole-rock and Trace Element Analyses, Metasediments, Nicholson Bay Area

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	LOI	Ni	Co	Cr	V	Au	Pb	Cu	Zn
CD27	ND	12.1	12.5	.09	16.47	1.00	.59	.70	.07	.03	ND	188	49	230	316	20	3	79	71
CD60	ND	2.0	7.0	12.7	15.8	<.01	.17	.05	.19	.03	ND	370	19	1594	70	-	2	6	19
CD62	ND	.1	4.2	.03	.03	.01	.17	<.01	.01	.03	ND	15	3	577	42	150	3	2	3
CD71	ND	.2	4.1	21.3	15.5	.02	.15	<.01	.51	<.01	ND	6	2	65	3	-	2	4	24
TS163									.51	<.01	ND	7	2	17	5	-	4	1	35
TS164												745	41	ND	ND	-	2	56	14
TS165												31	20	ND	ND	-	65	14	7
TS166												52	7	ND	ND	-	3	27	3
TS169						Not Determined						170	12	ND	ND	180	18	48	7
TS170												159	28	ND	ND	-	5	253	5
TS182												445	126	ND	ND	140	56	125	8
TS183												150	24	ND	ND	100	14	39	9
TS214												62	60	ND	ND	-	0	122	12
TS272												684	57	ND	ND	-	3	29	13
												73	39	ND	ND	20	6	134	7

See Table 1 for footnotes.
Samples CD-27, TS-163 and TS-214 are amphibolite; remaining samples are calcareous quartzites and calc-silicates.
TS samples are from a sulphide-rich zone underlying the ultramafic complex.

and dips are gently to moderately west. On the western margin of the complex, along the east shore of Nicholson Bay, the ultramafic complex appears to be folded and repeated across an antiformal core of quartzite (Fig. 1). Minor fold structures are open and plunge gently to the south in this region. The overall outcrop pattern of the complex suggests a flat-lying sheet, openly folded about gently and doubly-plunging north-south axes. Contacts between mafic and ultramafic rocks appear to be mainly flat lying, lending some support to this interpretation. There is presently insufficient data to determine whether the complex is concordant or disconcordant to the metasediments.

Geochemistry

Presently available geochemical data are summarized in Tables 1 and 2[1]. It is emphasized that these data are preliminary and not fully checked, although standards and replicate analyses were within acceptable limits. The ultramafic rocks are characterized by high loss on ignition (LOI), compatible with serpentinization, as well as by high magnesium, nickel, cobalt and chromium, and low potassium, sodium, titanium, zirconium and yttrium. The erratic values recorded for CaO, the generally low but also erratic $CaO:Al_2O_3$ ratios, and the erratic $CaO:MgO$ ratios suggest that there has been chemical alteration, at least in respect to calcium.

The mafic rocks fall into two groups based on their aluminum and magnesium values. Samples described in the field as fine-grained mafic rocks contain less magnesium than the ultramafics, which are correspondingly depleted in nickel, but contain more calcium, aluminum and silica. The medium-grained mafic rocks are characterized by much lower magnesium, nickel and chromium and much higher aluminum, potassium and sodium than the fine-grained mafics.

All the samples reported in Table 1 were analyzed for gold and seven of these samples for platinum, yielding values of less than 5 ppb for gold and below 2 ppb for platinum. Another suite of samples (not reported in Table 1) yielded trace values for gold (less than 10 ppb), platinum (less than 5 ppb) and palladium (less than 15 ppb).

Table 2 summarizes the analytical data from the metasediments. Of particular interest are the anomalous gold values of up to 180 ppb from the sulphide-rich rocks which appear to underlie the ultramafic complex.

Summary

Field relationships are insufficiently detailed to establish whether the complex is intrusive or extrusive. Serpentinization and metamorphic recrystallization to amphibolite facies assemblages have masked primary mesoscopic internal structures. Contacts of the complex are generally not exposed and the underlying rocks are poorly bedded to massive so that concordance or disconcordance of the complex has not been established. The overall outcrop pattern and small-scale structural observations suggest that it is a relatively flat lying, gently folded sheet which has little depth extension. Outcrop patterns of other ultramafic bodies in the Nicholson Bay - Goldfields area are consistent with this geometry. The magnetic response over the ultramafic complex is not

[1] Major and minor oxides in percent; trace metals in ppm, except gold in ppb.

unusually strong as might be anticipated if there was depth extension.

Geochemical analyses indicate three distinct groups of rocks which approximate peridotite, pyroxenite and basalt in composition and are distinguished in the field as ultramafic rocks, fine-grained mafic rocks and medium-grained mafic rocks respectively. The ultramafic rocks are chemically similar to komatiites (Arndt and Nisbet, 1981) in that they show low values of sodium, potassium, titanium, zirconium and yttrium, high nickel, cobalt, chromium and magnesium (MgO greater than 18 percent anhydrous). However, for the most part, they have an unacceptably low $CaO:Al_2O_3$ ratio, although the ratio is highly erratic as is the ratio of CaO to other oxides. As the rocks are altered, the $CaO:Al_2O_3$ ratio is deemed to have little significance.

If the komatiitic affinity of the ultramafics is accepted, then their association with a stable shelf environment, as suggested by the coarse clastics and carbonates of the Goldfields - Nicholson Bay area (Sibbald and Lewry, 1980) is unusual if not unprecedented. Schau (1977), for example, has reported a komatiite-quartzite association in the Archean Prince Albert Group in the Hayes River area of the Northwest Territories, northern Churchill Province. Here, the komatiitic rocks form sills, dykes and flows and as in present area are greatly subordinate to the surrounding metasediments.

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Project 8302/8315

Geochemical Studies in the Flin Flon and Hanson Lake Areas

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This report deals with two investigations, the Hanson Lake Geochemical Project (8302) and the Flin Flon Base Metals Project (8315). Limited field investigations were carried out this summer around Flin Flon, to collect more samples of late dykes, and in the Hanson Lake - Limestone Lake area, to complete sample coverage and obtain preliminary data on exposed volcanics close to the Bigstone Lake Cu-Zn deposit. One of the authors (JWG) has obtained a student fellowship which will allow a continuation of the Hanson Lake project (as a laboratory study) through 1986.

History of the Projects

The Flin Flon project was initiated in 1978 with a compilation of non-confidential assessment files housed with Saskatchewan Energy and Mines (McDougall et al., 1983) and continued through 1983 with the sampling and/or mapping of the East Amisk, Annabel and Hamell Lake areas. About 2400 bedrock samples were collected and analyzed over that period.

The Hanson Lake project was initiated in 1982 when about 500 samples were selected from Saskatchewan Geological Survey collections. In 1983 another 200 samples were collected and analyzed following the methods used in the Flin Flon project.

Data Collection and Interpretation

The 3000 or more samples have been analyzed for major and selected trace elements as follows (Table 1): The major elements SiO_2, TiO_2, Al_2O_3, total Fe_2O_3, MnO, MgO, CaO, P_2O_5, Ba, Sr, V were analyzed by inductively coupled plasma (ICP) methods. Na_2O and K_2O were determined using atomic absorption spectrophotometry (AA). FeO was determined using a modified dichromate titration technique. Loss-on-ignition (LOI) and H_2O^- determinations were carried out on most samples, in preference to H_2O^+ and CO_2, as the method is less expensive. Cu, Zn, Ni, Rb, Sr, Y, Zr, Nb, Th, U, Pb, and Ba were determined on pelletized powders using X-ray fluorescence spectroscopy (XRF). The XRF

Table 1 - Analytical Methods and Precision

Element	Method	Precision (as S.D. ±)	
SiO_2	ICP	0.84	%
TiO_2	ICP	0.05	
Al_2O_3	ICP	0.26	
Fe_2O_3	ICP	0.26	
MnO	ICP	0.04	
FeO	Tit.	0.60	
MgO	ICP	0.29	
CaO	ICP	0.40	
Na_2O	AA	0.27	
K_2O	AA	0.04	
P_2O_5	ICP	0.04	
H_2O^-	Grav.	0.01	
LOI	Grav.	0.50	
Ba	ICP	40	ppm
Sr	ICP	8	
V	ICP	25	
Cu	XRF	2	
Zn	XRF	3	
Ni	XRF	4	
Rb	XRF	2	
Sr	XRF	1	
Y	XRF	1	
Zr	XRF	2	
Nb	XRF	1	
Th	XRF	1	
U	XRF	1	
Pb	XRF	1	
Ba	XRF	14	

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analyses were carried out at the University of Aston in Birmingham (UK); all other analyses were done at the University of Regina.

All data are currently stored on disc at the University of Regina Geochemical Laboratory along with other relevant information such as field identification and UTM coordinates. Since these data amount to some 700K of storage, the task of checking each entry and manipulating the data has proved extremely time consuming. At present, some data still require correction and some programs (such as cation norm calculations) have yet to be written.

The following, in terms of interpretation, is preliminary and subject to later modification.

Volatile Content

It is well known that fresh volcanic rocks, other than extremely alkaline types, contain less than 1 percent combined H_2O^+ and CO_2. The majority of the rocks used in this study average from 2 to 5 percent LOI. Petrographic study indicates that in most cases the LOI can be ascribed to loss of H_2O^+ derived from the amphiboles (and/or micas) which have totally replaced the primary anhydrous mafic minerals during metamorphism. In a few cases the presence of secondary calcite, as vein or vesicle infillings, suggests the LOI is due dominantly to loss of CO_2; in such samples the CaO values are invariably higher than normal. Irrespective of the nature of loss-on-ignition, it is clear that secondary processes such as hydrothermal activity and metamorphism have increased the volatile contents of the volcanic rocks. In order to standardize data handling, virtually all calculations and plotting are being made on a volatile-free basis. Although the absolute values change slightly upon recalculation to a dry basis, proportionality between elements and/or oxides is unaffected.

Rock Classification

During the course of these projects it has proved difficult to standardize rock identification due to the various geologists involved. In order to overcome this problem, the volcanic flow rocks and intrusive rocks have been reclassified using a simple chemical scheme (Table 2). Obviously, the fundamental distinction between extrusive and intrusive remains as defined in the field, as do other dominantly texturally defined rock types such as tuff, agglomerate and greywacke. The scheme thus defined produces workable subfiles which can then be compared with the field identifications and used for data plotting. The chemical reclassification is carried out on volatile-free analyses.

Volcanic Environment

The basalt and gabbro subfiles for the various areas are being studied using the various discriminant diagrams available in the literature (e.g. Erlank and Kable, 1976; Floyd and Winchester, 1975; Goldie, 1979; Hart et al., 1970; Pearce and Cann, 1973; Pearce et al., 1977; Pearce and Gale, 1977; Pearce and Norry, 1979; Smith and Smith, 1976; Stillman and Williams, 1978; Winchester and Floyd, 1976). The plots used to date are log P_2O_5 - log Zr (Pearce and Cann, 1973), log (Zr/Y) - log Zr (Pearce and Norry, 1979), Zr/Y - Ti/Y (Pearce and Gale, 1977) and Ti - Zr (Pearce and Gale, 1977).

Table 2 - Chemical Parameters Used to 'Reclassify' Flow and Intrusive Rocks

Flow rocks	Intrusive rocks	Classification SiO_2(%)	Classification MgO (%)
? Ultrabasic	?	<53	>18
Basalt	Gabbro	<53	-
Basaltic-andesite		53-56	-
	Diorite		
Andesite		56-62	-
Dacite	Granodiorite	62-68	-
Rhyolite	Granite	>68	-

Note: Other rocks remain as classified in the field (e.g. tuff, agglomerate, greywacke, shale)

Preliminary results for the East Amisk area provide a data plot within the field of mid-ocean ridge basalts (MORB). The Annabel and Hamell data are closer to island arc type in character. Clearly these results raise all sorts of questions regarding the Flin Flon volcanic belt in general. The authors prefer not to advance any petrogenetic models until much more work is carried out on the data over the next few months.

Acknowledgments

The authors wish to thank the officers of Hudson Bay Exploration and Development Co. Ltd. and Granges AB for access to various files, access to deposits and access to their geologists. Once again John Siryj is thanked and complimented for his weekly venue that allowed wide-ranging geological discussions.

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Saskatchewan Mineral Deposits Index

by Virginia Harris

The Saskatchewan Mineral Deposits Index (SMDI) has the objective of aiding mineral exploration and resource planning in northern Saskatchewan.

The SMDI results from:

(1) systematic examination of all assessment reports, unpublished and published geological reports and technical papers;
(2) recognition of mineral deposits identified therein;
(3) description of mineral deposits for the manual index; and
(4) condensed description of mineral deposits for the computer index.

Mineral deposits are described on a 5 by 8 inch file card to form the SMDI manual file,

Table 1. Saskatchewan Mineral Deposit Index by NTS Area

NTS Area	NTS Quadrangle															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
63E	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	X	-	-	-	-	-	-	X	X	-	-	-
L	-	-	-	-	-	-	-	X	X	X	X	X	X	X	X	X
M	X	X	X	X	X	X	X	X	-	X	X	X	X	X	X	-
N	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-
64D	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
E	X	X	X	X	X	X	-	X	-	X	X	X	X	X	X	X
L	-	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X
M	-	X	X	X	-	X	X	-	X	-	-	X	-	-	-	X
73I	-	-	-	X	-	-	-	-	X	-	X	-	-	X	X	X
O	-	-	-	-	-	-	X	X	X	-	-	-	-	X	X	X
P	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X
74A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
B	-	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X
C	-	-	-	-	-	-	-	X	X	X	-	-	-	-	-	X
F	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
G	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-
H	X	X	X	X	-	-	X	X	X	-	-	-	-	-	-	X
I	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X
K	-	-	-	-	X	X	-	-	-	-	X	X	-	-	-	-
N	-	-	-	-	X	X	X	X	X	X	X	X	X	X	X	X
O	-	X	-	-	X	X	X	X	X	X	-	X	X	-	-	X
P	X	X	X	X	X	X	X	X	X	X	X	X	-	X	-	-

X = available
- = not available (no known deposits/covered by Phanerozoic/located in Manitoba)

Note: SMDI location maps at 1:50,000 are available in all of the above areas except 63L-9 and -16, 64M-9, -12 and -16 and 74 O-10

and selected information from this file is coded for input into the computer index. Copies of all or selected parts (by area or commodity) of the manual and computer files which do not contain confidential information are available from the Saskatchewan Geological Survey on request. For each mineral deposit the following data are listed: main product or commodity (e.g. Ag, Au, Cu, U), name of property, NTS (National Topographic System) location, latitude and longitude, a brief description of the deposit and exploration work undertaken, and references/sources of information.

Mineral deposits are at present listed by commodity in a consecutive manner by NTS map sheet; for example, 64L-04-U-5 would be the fifth uranium deposit in map sheet 64L-04 and 64D-05-Au-1 would be the first gold deposit in 64D-05. This system allows retrieval of all deposits or any one deposit or commodity by map area. In addition, each deposit is given an index number. The SMDI system is similar to that used in the National Mineral Inventory and, where possible, the deposits have the same number in both files.

Mineral deposits are plotted on 1:253,440 (1 inch to 4 miles), 1:250,000 and 1:63,360 (1 inch to 1 mile) aeromagnetic maps and on 1:50,000 scale topographic maps. Also available on request are computer-plotted maps on mylar or paper at any scale for any commodity or combination of commodities. Present geographic coverage of the SMDI is illustrated in Table 1 and Fig. 1.

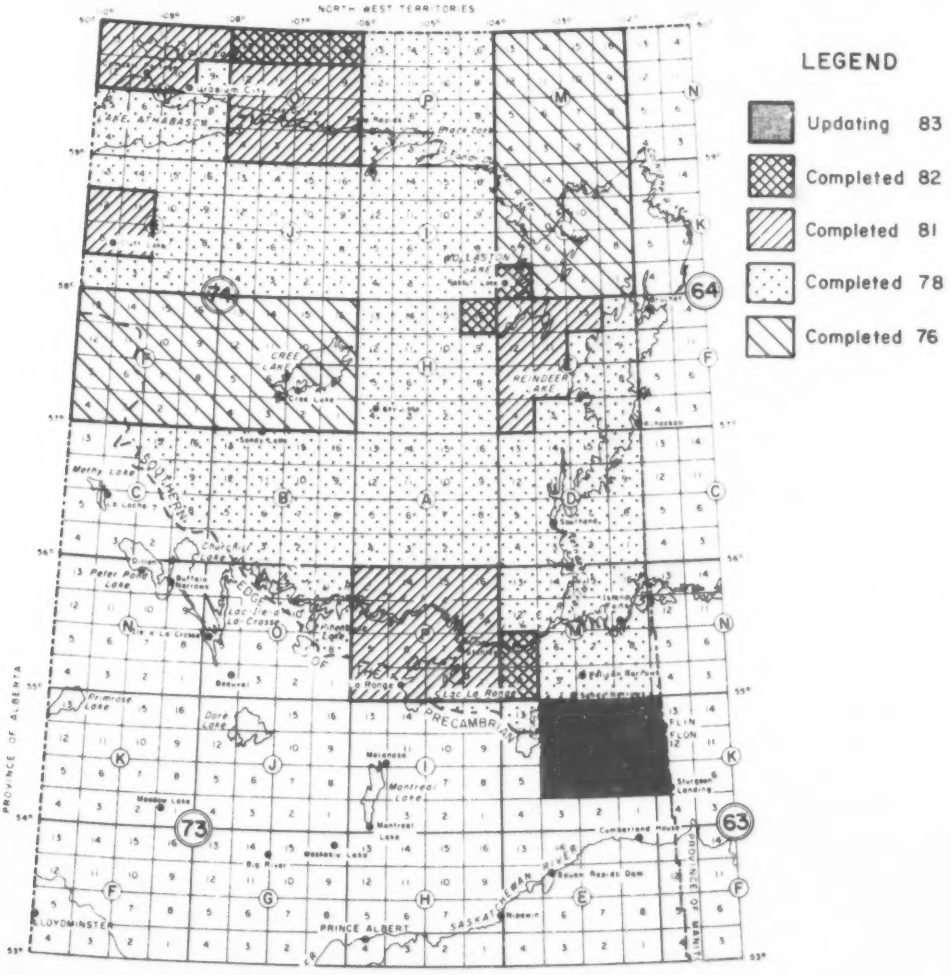

Figure 1 - Saskatchewan Mineral Deposit Index, coverage to September 1983.

Data Analysis Strategy for Lithogeochemistry: An Approach to the Study of Down-hole Profiles

by Michel Mellinger[1]

The Saskatchewan Research Council's Geochemistry and Data Analysis project emphasizes the development of expertise in basic methodology and the application of lithogeochemistry to mineral exploration. Further developments in the area of computer graphics applied to the analysis of geochemical data are noted here. In addition, results obtained in two areas of investigation are briefly reported.

Graphics Software for Data Analysis

The computer environment in which graphics software for data analysis is developed at SRC involves the integrated use of a mainframe computer for the handling of data management and processing, and of a stand-alone graphics workstation for the interactive graphical analysis of data and of results from data analysis (Mellinger, 1982).

The software that was designed and developed performs the following functions:

1) data transfer from the mainframe environment to the graphics workstation;
2) data file management, including the creation of data sub-files and the quick examination of data files using simple statistics and contingency tables;
3) detailed univariate analysis of the data using histograms;
4) detailed bivariate analysis of the data using bivariate plots;
5) detailed multivariate analysis of the data using factor plots and their associated information.

A series of SRC reports presenting the software design and usage of these computer programs is intended to be published shortly (Smith and Mellinger, in prep.).

A Data Analysis Strategy for Lithogeochemistry

The analysis of geochemical data involves the interpretation of data in terms of the many parameters that influence the geochemical behaviour of the elements. In order to arrive at a relevant interpretation of the data, the geochemist must use some data analysis strategy. The strategy that has been developed at SRC for lithogeochemistry is based on a multivariate approach, integrating petrogenetic information with chemical data.

The elements that may be analyzed in a rock sample are classified either as major or trace elements. Because we are interested in the study of element behaviour during geological processes, major and trace elements are defined following the paragenetic-thermodynamic approach of Korzhinskii (1959). Major elements are those which are essential constituents of the minerals present in the samples under study; they are 'framework' elements. Trace elements are those which occur in small quantity and which do not cause the appearance of new mineral phases; they are 'substitution' elements. The main parameters for major and trace element behaviour are summarized in Fig. 1, together with the expected direct causes for variations in their concentration in rocks.

The general data analysis and interpretation strategy that proceeds from such considerations is represented schematically in Fig. 2. Major and trace elements, selected on the basis of the petrography of the samples under study, are investigated

Major elements	Trace elements
(Definition)	
"framework" elements	"substitution" elements
(Behavior Parameters)	
chemical potential mineral stability	abundance/availability interaction with crystal structures
(Direct Causes for Variations in Data)	
variations in mineralogy	variations in mineralogy & in availability (rock specialization) & in crystallization sequence (geological process signature)

Figure 1 - The distinction between major and trace elements in lithogeochemistry.

[1]Resources Sector, Saskatchewan Research Council, Saskatoon.

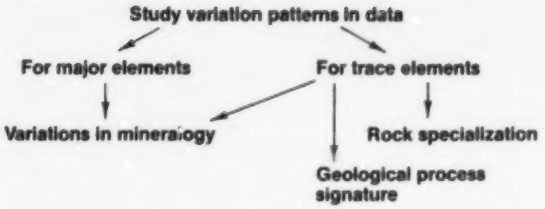

Figure 2 - A general strategy for the analysis and interpretation of lithogeochemical data.

separately for data variation patterns. A descriptive factor analysis method known as correspondence analysis is used (Benzecri et al., 1980). A factor space is obtained for each group of elements.

The major element factor space displays data structures related to mineralogical variations in the samples. At this stage, petrographic knowledge of the samples is required, so as to ensure relevant interpretation of the data structures with respect to petrography and to the geological processes that affected the samples.

The trace element factor space displays data structures arising from various causes. Firstly, variation patterns related to mineralogical (major element) variations are identified. In order to do this, the major elements are treated as supplementary variables and are projected into the trace element factor space; major element variations can then be located in this factor space and be related to some of the trace element variation patterns. Similarly, treating trace elements as supplementary variables when calculating the major element factor space helps clarify the degree and the nature of the overlap between trace and major element variation patterns. Secondly, the portion of the trace element factor space that cannot be correlated with mineralogical variations is interpreted in terms of rock specialization and of the geochemical signature of the relevant geological processes. Here again, useful information is generated only if the geochemist has a good knowledge of the geological history of the area under investigation; in this case, trace element geochemistry provides unique information.

A more complex description of this data analysis strategy, including the use of various data coding schemes and an example of application, has been submitted for publication elsewhere (Mellinger, 1983a).

The Multivariate Analysis of Down-hole Profiles

When studying chemical analyses of drill core samples from exploration drillholes, the explorationist is faced with several difficulties: (1) the chemical data may require some processing before useful information can be identified; (2) down-hole variations may result from a combination of background (primary) and alteration (secondary) characteristics; and (3) comparing and characterizing down-hole alteration profiles may be quite subjective.

The suggested approach for dealing with these difficulties is summarized in Fig. 3, using major elements. Firstly, variation patterns in the chemical data are extracted using correspondence analysis (Fig. 3, step a). This results in a set of factor coordinates, each of which is related to specific variations in the mineralogy of the samples under study (see above). Let us assume that, in the present case, factor F3 quantifies hydrothermal alteration (e.g. the illite/kaolinite ratio in samples from the Athabasca Group in northern Saskatchewan). In the next step, down-hole profiles of the F3 coordinate are calculated (Fig. 3, step b) for both background (B) and non-background (X) drillholes. As only true alteration profiles are sought, residual down-hole profiles are calculated as a series of positive or negative values (hatched areas between the B and X profiles, in Fig. 3). The resulting data table consists of

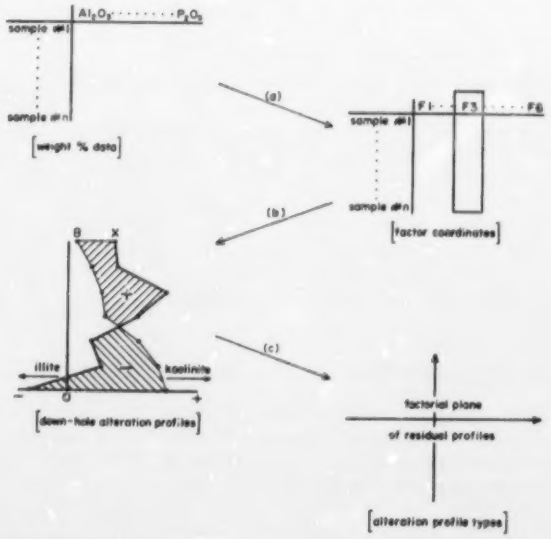

Figure 3 - Suggested approach for the characterization of down-hole alteration profiles (see text for explanations).

drillholes "measured for" successive residual values located at regular intervals along the drillhole axis. This new data table is submitted to correspondence analysis (Fig. 3, step c), which produces a topology of the types of down-hole alteration profiles in one or more factorial plots. On a factorial plot, each drillhole is represented as a symbol, and each depth interval at which a residual value was calculated is represented by two variables, one for positive residuals and the other for negative residuals.

This approach was applied to exploration data from the southeastern part of the Athabasca Basin (Mellinger, 1983b). It was successful in characterizing various types of down-hole alteration profiles related to the illitization and kaolinitization of sandstone samples from the Athabasca Group.

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Lithogeochemistry of the Athabasca Group

by D. H. Quirt[1]

Regional lithogeochemistry has increasingly become an accepted tool to discriminate between favourable or potentially mineralized areas and unfavourable or background areas. To date, the lithogeochemical characteristics of the Athabasca Group sandstones have not been studied on a basin-wide scale, despite the numerous mineralized zones discovered within the Athabasca Basin.

This study, as part of the Saskatchewan Research Council's comprehensive investigation into the relationships between uranium mineralization and the diagenetic and burial history of the Athabasca Group, develops a base of major and trace element rock compositional data. This data base includes background elemental concentrations for the various formations of the Athabasca Group and elemental concentrations for sandstone alteration haloes surrounding known uranium mineralization and for altered sandstones within the mineralized zones proper. Clay and accessory mineral proportions for all samples are appended to the data set. The aims of this investigation are to determine the lithogeochemical character of the Athabasca sandstone and to apply this information to investigations into the metallogenesis of the deposits as well as to mineral exploration in the region.

Progress to date has been restricted to sampling, sample analysis and data organization. Approximately 450 background sandstone samples have been taken from the same deep stratigraphic drillhole cores used by Ramaekers (1979, 1980, 1981), Hoeve (1980) and Hoeve et al. (1981) for lithostratigraphy and clay mineral stratigraphy respectively. These were supplemented by background samples from the economically important southeastern corner of the basin.

The samples have been analyzed for 35 major and trace elements at the Saskatchewan Research Council geochemistry laboratory, primarily using AAS and ICPS, for Al, total Fe, K, Mg, Na, Ca, Ti, P, Mn, Ni, Cu, Pb, Zn, Li, Rb, Sr, Au, Ag, As, V, U, Th, Co, Mo, Zr, Cd, Cr, Be, B, Y, La and Ba. CO_2, LOI and Fe^{+2} were also determined for each sample. The analytical data were organized into a Lithogeochemical Data File (Mellinger, 1983) with the clay and accessory mineral data added as supplementary items. This file format has been found convenient for simple univariate and bivariate statistics, as well as for more formal statistical analysis of the data.

[1]Resources Sector, Saskatchewan Research Council, Saskatoon

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Uranium Metallogenic Studies: Clay Mineral Distribution in the Athabasca Group, Southwest Part of the Basin

by J. Hoeve[1], D. Quirt[1] and D. Alonso[2]

During the past few years we have conducted a program to study the relationships between Athabasca Group diagenesis and host rock alteration in unconformity-type uranium deposits. Clay mineral distribution and diagenetic patterns in the Athabasca Group have been compared with clay mineral host rock alteration at individual deposits (Hoeve et al., 1981, a, b; Hoeve, in press).

The application of clay mineralogy to stratigraphic interpretation has been demonstrated (Hoeve et al., 1981a) and in this article we report on the clay mineral stratigraphy in the little-known southwestern corner of the Athabasca Basin.

[1]Saskatchewan Research Council, Saskatoon.
[2]AMOK Exploration Ltd.

Clay Mineral Stratigraphy

Core samples were taken at 5 to 10 m intervals from several drillholes located to the south, east and north of the Carswell structure (Fig. 1; drillholes AS1, AS2, CAR 114, BM-1 and CSP10-1). The interstitial clay of these rocks was found to consist of the same mineral species as reported for other parts of the Athabasca Basin (i.e. varying proportions of kaolinite, illite and di, trioctahedral chlorite (sudoite)).

Using previously established correlations (Hoeve et al., 1981a), the clay mineral logs for these drillholes can be subdivided into distinct lithostratigraphic units (Figs. 2, 3, 4, 5 and 6).

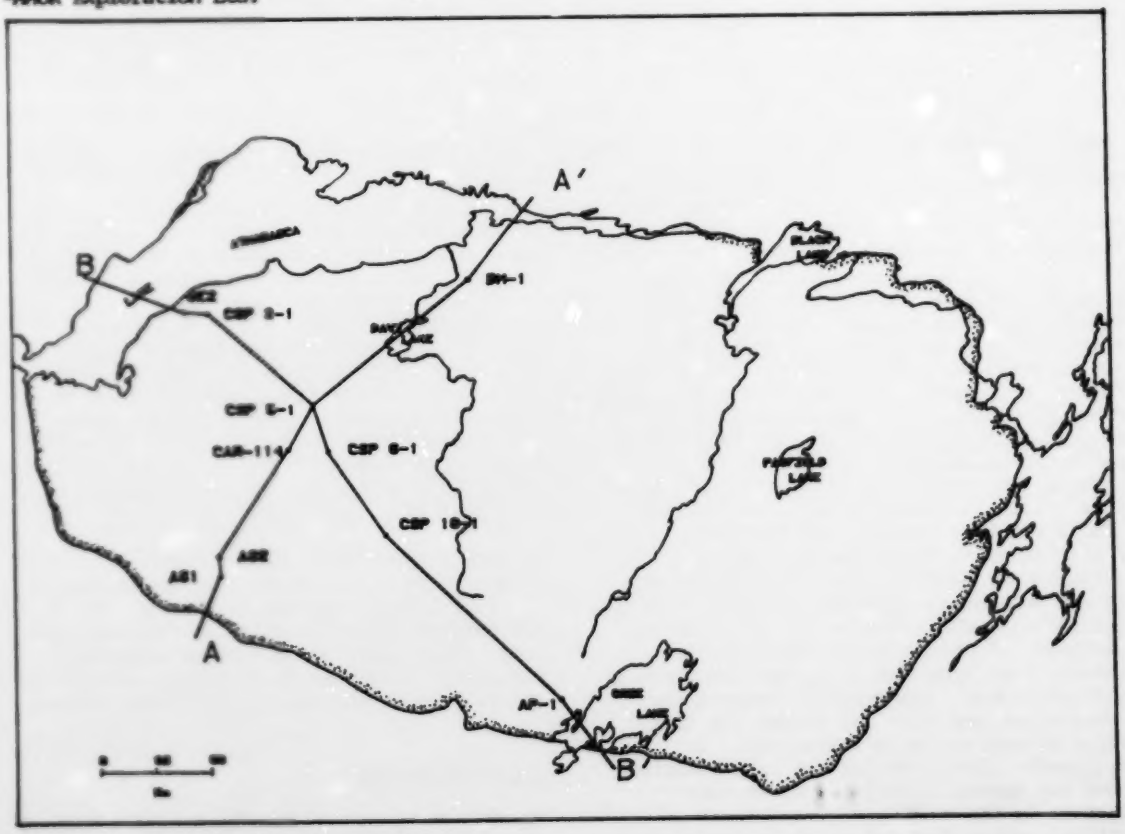

Figure 1 - Location of drillholes and cross-sections.

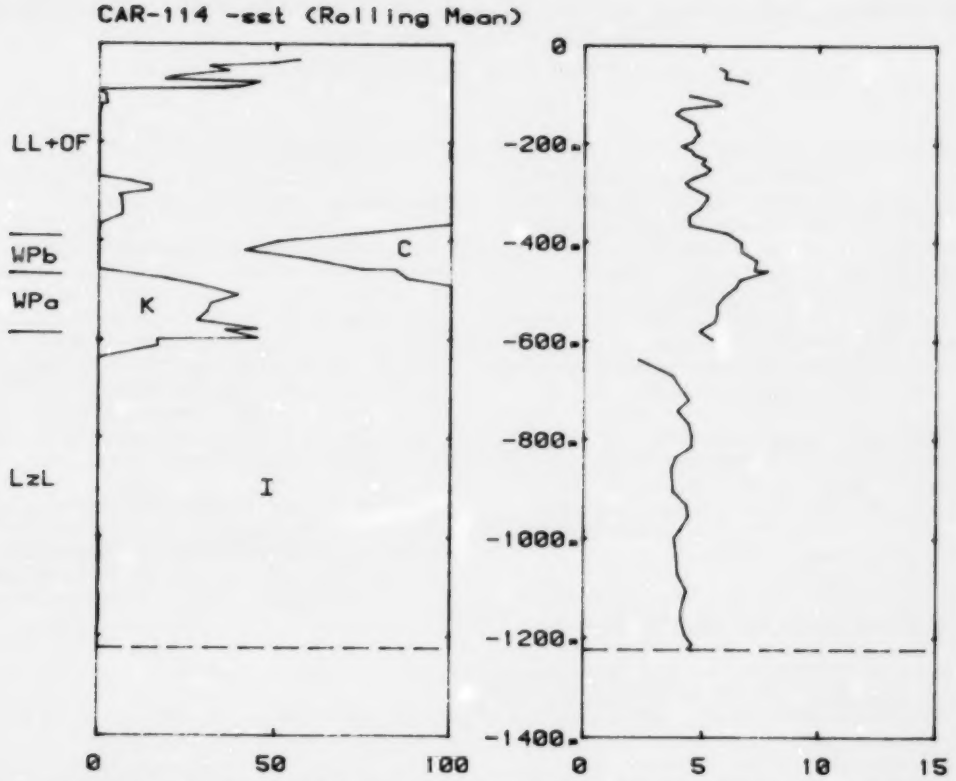

Figure 2 - Clay mineral log of drillhole CAR 114. Clay composition: K, kaolinite; I, illite; C, chlorite. Athabasca Group stratigraphy: FPa, b, Fair Point Formation a and b; MFa, b, c, d, Manitou Falls Formation a, b, c and d; LzL, Lazenby Lake Formation; WPa, b, Wolverine Point Formation a and b; LL, Locker Lake Formation; OF, Otherside Formation.

In drillhole CAR 114, located to the east of the Carswell structure, the Manitou Falls and Fair Point Formations are both absent and, instead, 600 m of Lazenby Lake Formation is found underlying the lower Wolverine Point Formation. In drillhole AS1, to the south of the Carswell stucture, 350 m of Lazenby Lake Formation is sandwiched between the Wolverine Point Formation and a thin 100 m intersection of Fair Point Formation, whereas AS2, though not reaching basement, intersects 400 m of Lazenby Lake Formation before terminating in this unit. In drillhole BM-1, the Lazenby Lake Formation is absent and the lower Wolverine Point Formation is directly underlain by upper Manitou Falls Formation. In the previously reported drillholes CSP2-1 and LAJV-2 (=GE2), located to the north and northwest of the Carswell structure, the Lazenby Lake Formation is present as a poorly defined, 100 m thick interval between the lower Wolverine Point and either the Fair Point or Manitou Falls Formations. In drillhole CSP8-1, the Lazenby Lake Formation does not appear to be present, whereas farther to the southeast in drillhole CSP10-1, which does not reach basement, it is at least 200 m thick.

These relationships indicate that the Lazenby Lake Formation is restricted to the Jackfish sub-basin of Ramaekers (1980) and forms a thick wedge which undergoes rapid northeastward thinning over the Patterson High (Figs. 7 and 8). The Lazenby Lake Formation occurs between the Fair Point and Manitou Falls Formations, against which it onlaps to the west, north and east. This interpretation is consistent with Ramaekers' (1980) observation of increasing grain size towards the southwest, indicating sediment transport from that direction.

We here propose that the Lazenby Lake Formation is stratigraphically equivalent to the Fair Point Formation in the west and to the Manitou Falls Formation in the north and east. This equivalence further supports Ramaekers' (1980) argument for correlation of the Fair Point and Manitou Falls Formations.

Acknowledgments

We wish to thank Marline Oil Ltd. and Bonn Energy Corporation for permission to publish the logs for drillholes AS1 and AS2.

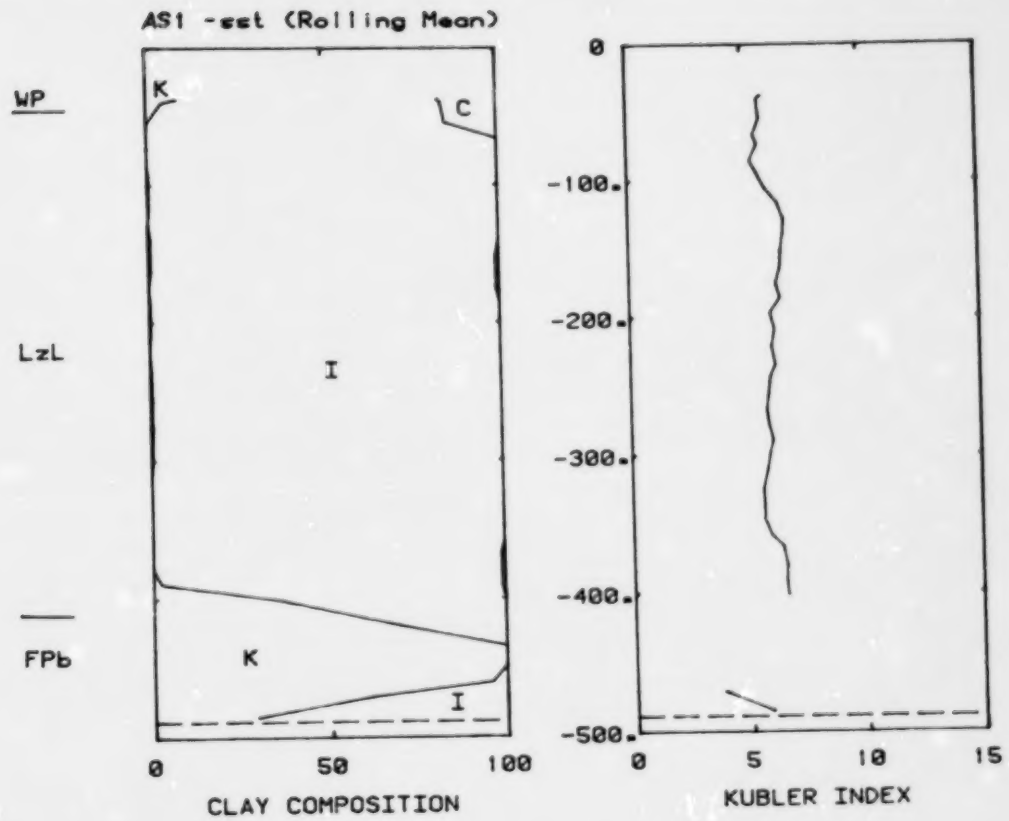

Figure 3 - Clay mineral log of drillhole AS1. See Fig. 2 for explanation of symbols.

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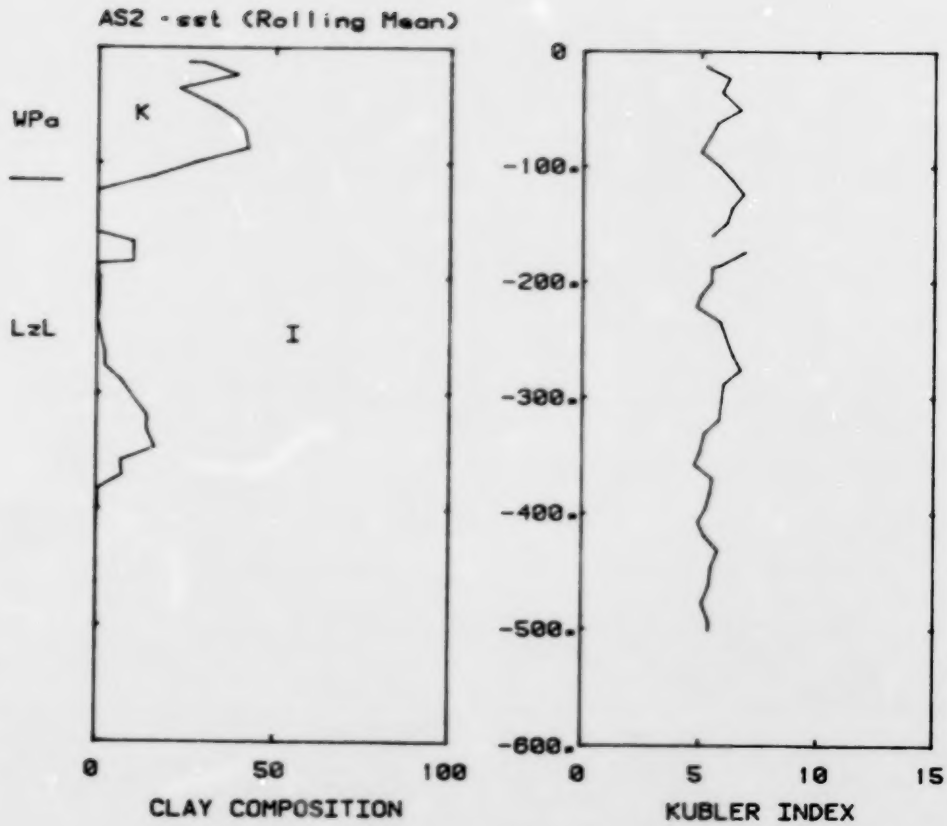

Figure 4 - Clay mineral log of drillhole AS2. See Fig. 2 for explanation of symbols.

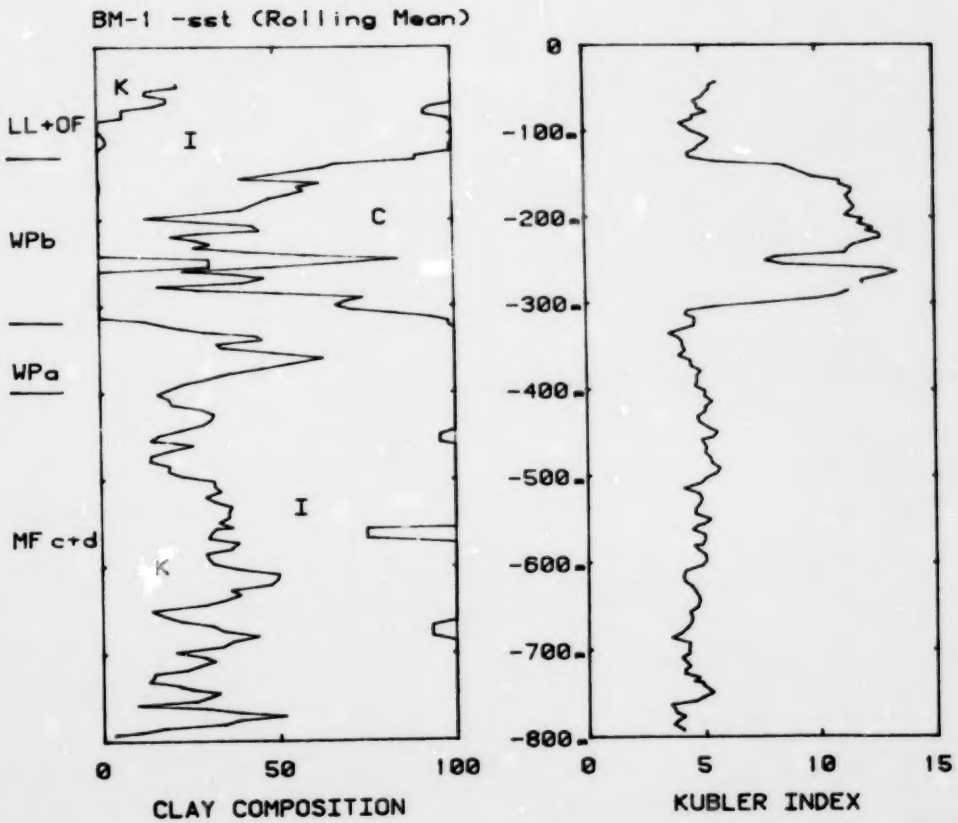

Figure 5 - Clay mineral log of drillhole BM-1. See Fig. 2 for explanation of symbols.

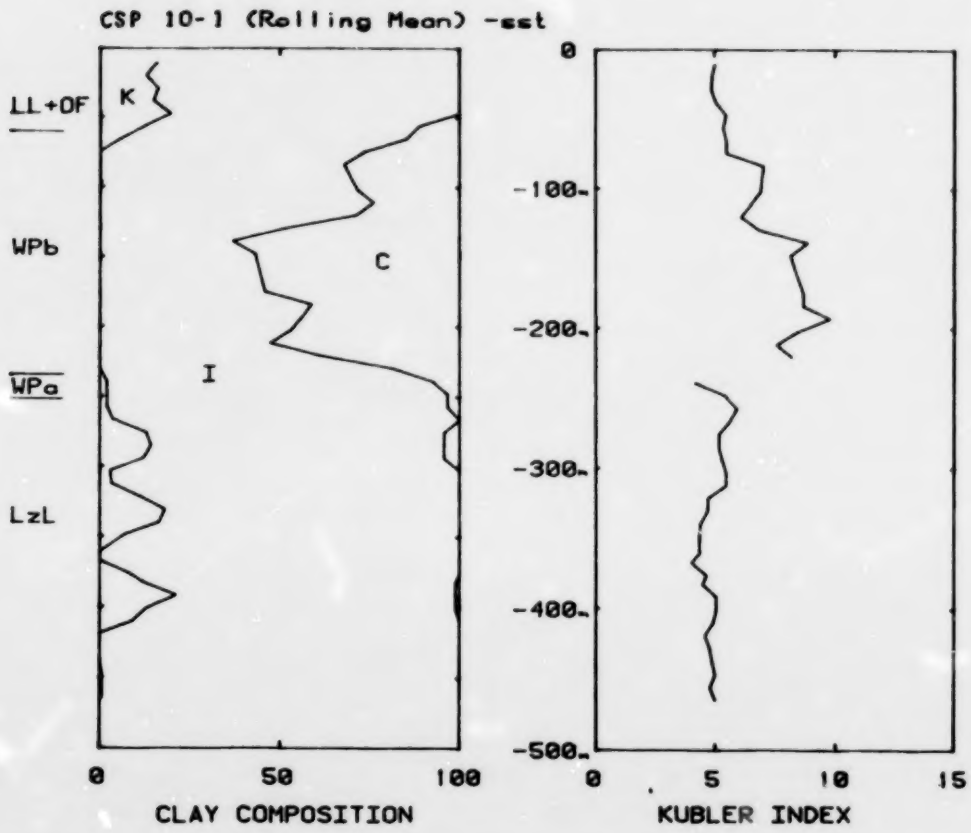

Figure 6 - Clay mineral log of drillhole CSP10-1. See Fig. 2 for explanation of symbols.

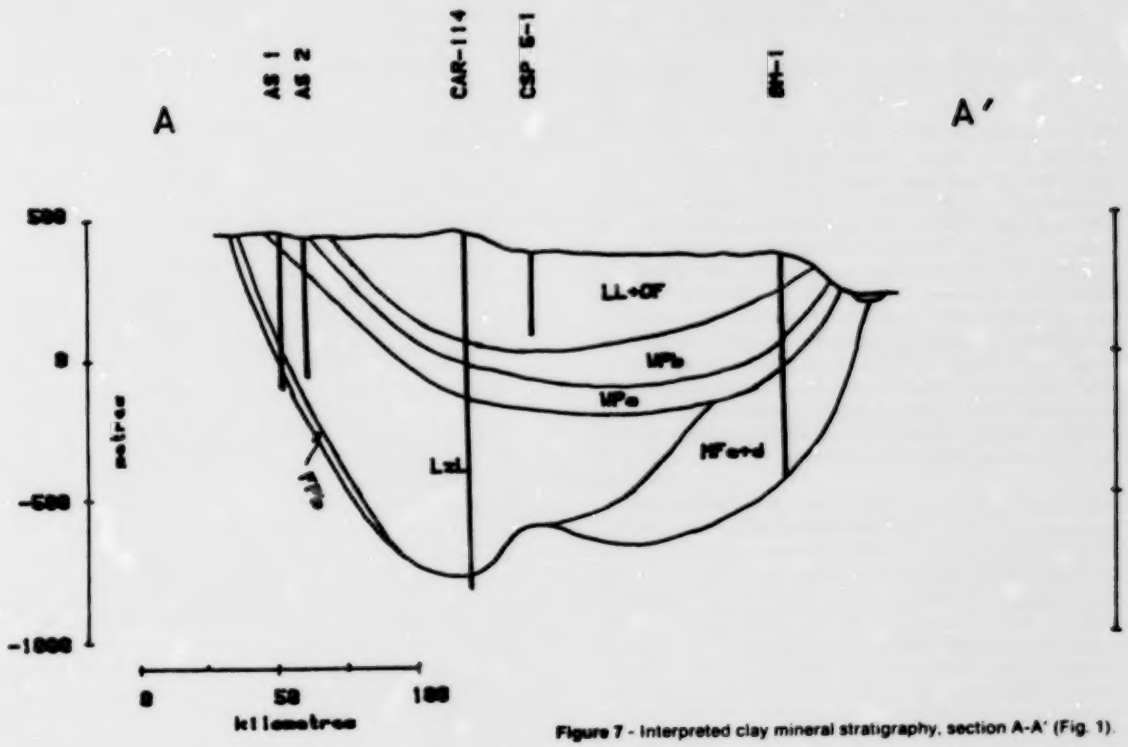

Figure 7 - Interpreted clay mineral stratigraphy, section A-A' (Fig. 1).

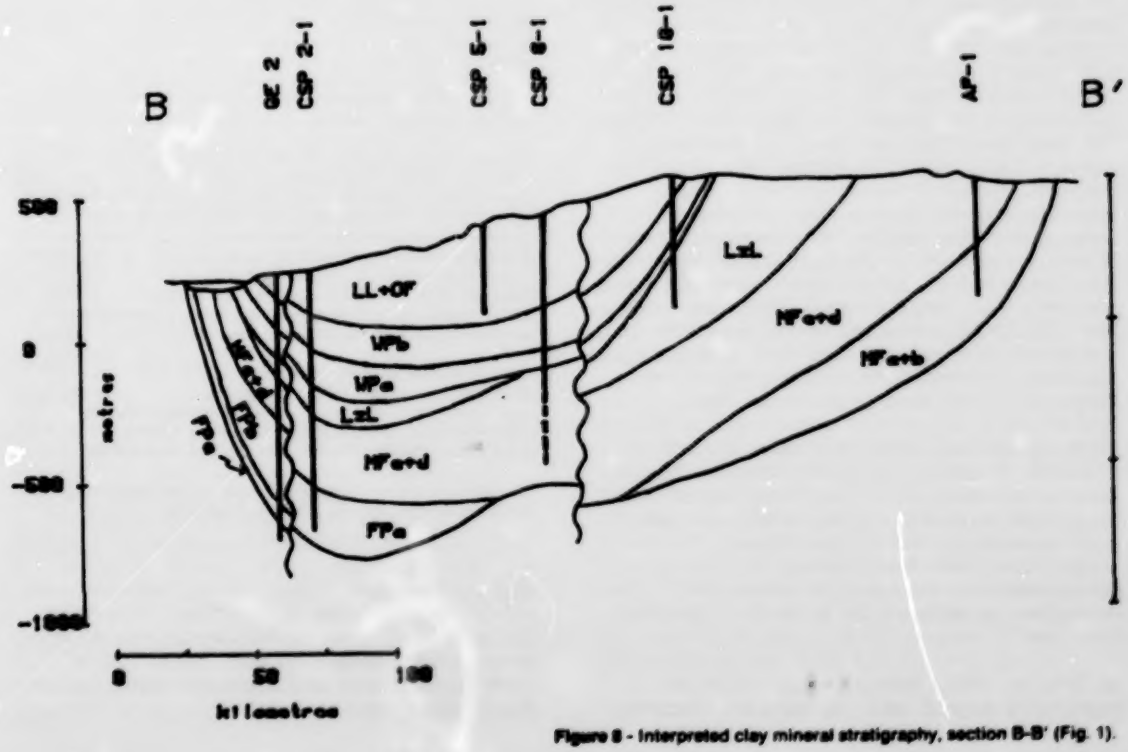

Figure 8 - Interpreted clay mineral stratigraphy, section B-B' (Fig. 1).

Mineral Exploration Activity in the La Ronge Mining District and Athabasca Basin

by A. J. Gracie

Uranium exploration has continued to decline in the past year. Most drill programs tested targets in the southeast part of the Athabasca Group basin. Seru Nucleaire made a significant discovery south of Waterbury Lake, clearly demonstrating that the potential of this region is not exhausted. Many mineral properties in the centre of the basin have now lapsed and nearly all the sandstone perimeter projects on the southern margin of the basin to the west of Key Lake are inactive. The level of exploration drilling will likely decline again next winter despite the high discovery rate and a rise in the price of uranium.

Key Lake Mining Corporation Ltd. anticipates production from the Key Lake mill this fall. Eldor Mines Ltd. has completed construction of the earth filled abutments of the Collins Bay B Zone dyke and the deposit is scheduled for production in 1985. The Canadian Occidental Petroleum Ltd./Inco Metals joint venture has announced plans for a two-year pilot mine on the McClean Lake deposits beginning in 1984. This project will be viewed extremely closely by other companies active in the area, as it will be the first attempt at underground mining of the very high grade uranium ores. If successful, it will lend a new perspective to the development of the deeper unconformity-type deposits. The Canada Wide Mines Ltd. 'Midwest Lake' project is still dormant. Asamera Inc., who will retain only a 1 percent carried interest in their joint venture with the Saskatchewan Mining Development Corporation and Reserve Oil and Minerals Corporation at Dawn Lake, reported that the company had increased reserves by 50 percent to 15,386 t U metal (Northern Miner, Nov. 25, 1982). Texaco Canada Resources Ltd. and Idemitsu Kosan Co. Ltd. have acquired an interest in several promising properties in the active part of the Athabasca Basin.

Gold exploration activity has continued to increase in the La Ronge and Glennie Lake Domains and is presently at its highest level in several decades. An encouraging recent announcement by the Starrex Mining Corporation Ltd./Saskatchewan Mining Development Corporation joint venture describes an exceptional hole from the Star Lake area.

In October 1982, Granges Exploration AB reported a significant copper-zinc discovery at Bigstone Lake. The company has now taken out a series of new prospecting permits in the adjoining area in the south part of the Glennie Lake Domain to test metavolcanic rocks lying under and along the margin of the Phanerozoic cover.

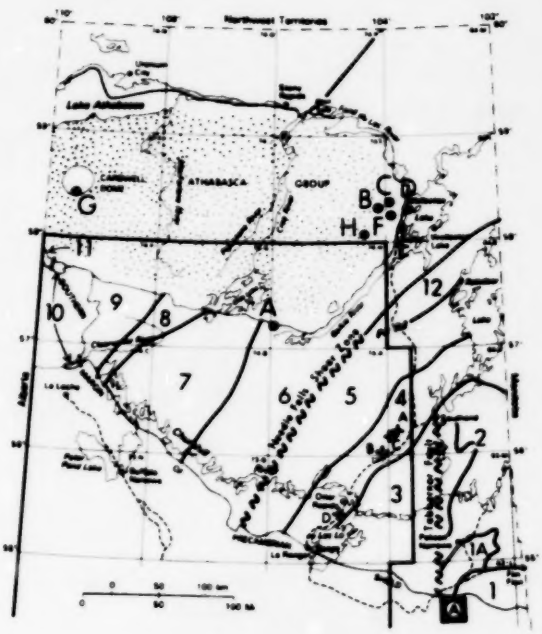

Figure 1 - Location of the La Ronge Mining District in relation to geological domains in the Precambrian Shield. Numbered domains: 1. Flin Flon; 1A. Hanson Lake Block; 2. Kisseynew; 3. Glennie Lake; 4. La Ronge; 5. Rottenstone; 6. Wollaston; 7. Mudjatik; 8. Virgin River; 9. Western Granulite; 10. Clearwater; 11. Firebag; 12. Peter Lake.

Current uranium mines, potential mines and major exploration locations related to the Athabasca Basin (indicated by ⊕): A. Key Lake Mining Corporation, Key Lake; B. Canada Wide Mines Ltd., 'Midwest Lake'; C. Saskatchewan Mining Development Corporation joint venture, Dawn Lake; D. Eldor Mines Ltd., Collins Bay and Eagle Point zones; E. Eldor Mines Ltd., Rabbit Lake; F. Canadian Occidental Petroleum Ltd./Inco, McClean Lake; G. Amok Ltd., Cluff Lake; H. Seru Nucleaire (Canada) Ltee., Waterbury Lake joint venture. Shading represents interior area where the Athabasca Group exceeds 500 m in thickness.

Current gold exploration locations (indicated by +): A. Golden Rule Resources Ltd., Wedge and Weedy Lake ocurrences; B. Starrex Mining Corporation Ltd./Saskatchewan Mining Development Corporation, Star Lake joint venture; C. Weddy Lake Resources Inc., Komis; D. Sulphide Lake area.

Current base metal exploration locations (indicated by ▭) A. Granges Exploration AB, Bigstone Lake area.

Three all-weather highways, to Rabbit Lake, Cluff Lake and Key Lake now give access to northern Saskatchewan and major improvements in Highway 106 make travel from La Ronge or Prince Albert to Flin Flon much faster.

Uranium

Athabasca Group Perimeter

Exploration drill programs concentrated on detection of conductor- and/or fault-related unconformity deposits using the 'Key Lake model' as a basis. These programs are now mostly limited to the east and southeast parts of the Athabasca Group basin, which is underlain by the Mudjatik Domain, the Wollaston Domain and the Wollaston/Mudjatik Transition Zone. Irrespective of this restriction on exploration activity, few of the mineral properties on other parts of the perimeter have lapsed. Many mineral prospecting permits have been replaced by claim blocks. The joint venture operated by Seru Nucleaire reported a discovery at the south end of Waterbury Lake at depths of 410 to 440 m. The Saskatchewan Mining Development Corporation, a member of the Waterbury joint venture, announced in their 1982 annual report that 22 of 26 holes drilled by the end of 1982 on sections 100 to 150 m apart contained uranium mineralization over a strike length of 1200 m. Three holes gave very good intersections of 5.42 percent U over 4.3 m, 11.27 percent U over 6.5 m and 11.36 percent U over 6.7 m.

Exploration inside the deeper part of the Athabasca basin perimeter area has revealed several areas with radioactive boulders, leading to recognition in the sandstone of fault drill targets and conductor- and/or fault-controlled targets in the metamorphosed basement. Identification of clay mineral alteration, bleaching and trace metal haloes has also proved valuable in target selection.

Athabasca Group Interior

The majority of the properties in the Athabasca basin interior have now lapsed and there has been little activity except along the Read-Close-Waterbury Lakes trend which crosses the boundary between the perimeter and interior divisions of the basin. Exploration methods resemble those described for the deeper part of the perimeter area.

Crystalline Basement

Companies have continued to show little interest in uranium exploration outside the Athabasca basin, although mineralization is known to occur at some considerable depth below the sub-Athabasca Group unconformity, as for example in the Eagle Point deposit on the west side of Collins Bay. Only two programs - by AGIP and Minatco - are known to have drilled targets.

Gold

Although no property is in production in the area, gold exploration has increased in both the La Ronge and Glennie Lake Domains in response to the Hemlo discovery and to the relatively stable, high price of gold, as well as favourable price projections for the metal. Gold programs include both grass root ventures and attempts to upgrade existing showings. Much of the existing exploration effort has depended on underwritings to small companies, many with Saskatchewan investors as their principals.

Favourable open ground is now scarce in the La Ronge Domain and staking has overflowed to areas of possible gold potential in the Glennie Lake Domain to the east. The best hole reported this year is from the old Kahn 18 property at Star Lake, presently held by a Starrex Mining Corporation Ltd./Saskatchewan Development Corporation joint venture. Hole SL-83-21 encountered gold mineralization grading 43.21 g/t Au over a continuous 15.39 m section from 69.03 to 84.42 m (interim Shareholder Report, Aug. 30, 1983). The true width is not yet available but is between 10.05 and 12.19 m. Mafic dykes cut an intrusion of syenodiorite to monzonite composition which, where sheared, may contain mineralization. The high gold values occur in pyrite- and quartz-rich zones.

Golden Rule Resources Ltd. reported an interesting new find at Wedge Lake and upgraded the old Weedy Lake B zone. At Wedge Lake, 29 drill holes outline a zone of mineralization of about 544,311 t grading 6.17 g/t Au (Canarim Corporate Profile Release, Sept. 1983) . These holes cut gold values in a siliceous breccia unit closely related to a mixed sulphide-oxide-silicate facies iron formation (Golden Rule Resources Ltd. News Release, June 27, 1983). At Weedy Lake, 30 holes outline approximately 997,000 t grading 4.45 g/t Au within a quartz- and pyrite-rich shear zone in granodiorite and 3,630,000 t grading 2.05 g/t Au surrounding this zone (Canarim Corporate Profile Release, Sept. 1983). Recent drilling intersected the 'C' zone, consisting of a narrow, high-grade, quartz-filled shear which yielded a best intersection of 29.49 g/t Au over 2.5 m.

Waddy Lake Resources Inc. published drill-indicated and probable ore reserves for the Komis property of 1,457,000 t grading 3.77 g/t Au cut or 5.14 g/t Au uncut (Canarim Corporate Profile Release, Sept. 1982) . A total of 2,990,000 t of all categories of reserves grading 5.14 g/t Au may exist on the property if the three major zones are projected to 400 m.

The Sulphide-Contact-MacKay Lakes section of the Lac La Ronge Provincial Park is open for mineral exploration work. Although little exploration has been conducted to date, there has been new staking activity in the area. To the east in the Glennie Lake Domain, Cominco Ltd. and Carina Mineral Resources Corporation Ltd. carried out gold exploration programs respectively on their Laonil and Brownell Lakes properties.

Base Metals

The level of interest in exploration for base metals remains rather low. Granges Exploration AB took out two new permits in the La Ronge Mining District following their copper-zinc discovery at Bigstone Lake. These permits overlap the Phanerozoic/ Precambrian contact at the south end of the Glennie Lake Domain. Saskatchewan Mining Development Corporation operated base metal projects in the La Ronge Domain.

Mineral Exploration Activity in the Reindeer Mining District

by J. G. Pearson

During 1983, exploration activity for gold and base metals in the Flin Flon and Hanson Lake areas of the Reindeer Mining District increased markedly. The reasons for this appear to be twofold. The Bigstone Cu-Zn discovery by Granges Exploration AB in essentially unexplored volcanic rocks provided an impetus to land acquisition in the Glennie Lake Domain, the Flin Flon Domain and their extensions under Paleozoic rocks to the south. The presence of historic gold occurrences in the Flin Flon area, coupled with the development by Flin Flon Mines Ltd. of the Rio zone south of Creighton, has generated interest in this region. Competition for ground encompassing or near gold showings is intense.

During the past year, five permits were taken out, totalling 3856.47 km^2 (952,955 acres), while 411.16 km^2 (101,600 acres) were staked as claims and claim blocks. All of the permits were taken out on ground covering the Flin Flon and Glennie Lake Domains and their extension beneath Paleozoic and Cretaceous rocks.

This compares with 1982 figures of 1524.58 km^2 (376,732 acres) in permits and 1666.9 km^2 (411,900 acres) in claim blocks and claims (excluding those claim blocks staked to reduce permits).

During the past year, nine permits comprising 6188.96 km^2 (1,529,325 acres) and 678 km^2 (167,537 acres) in claims and claim blocks were allowed to lapse. All of the permits were in the Rottenstone, Wollaston and Mudjatik Domains.

Base Metals

Granges Exploration AB maintained a very active exploration program in the Flin Flon area (Fig. 1), concentrating their efforts on the Oskikebuk volcanic belt and its extension beneath the Paleozoics. This program comprised several hundred kilometres of linecutting and MaxMin II EM and magnetometer surveys. Twenty-four diamond-drillholes totalling 2000 m tested anomalies. In addition, Granges carried out a 6500 m

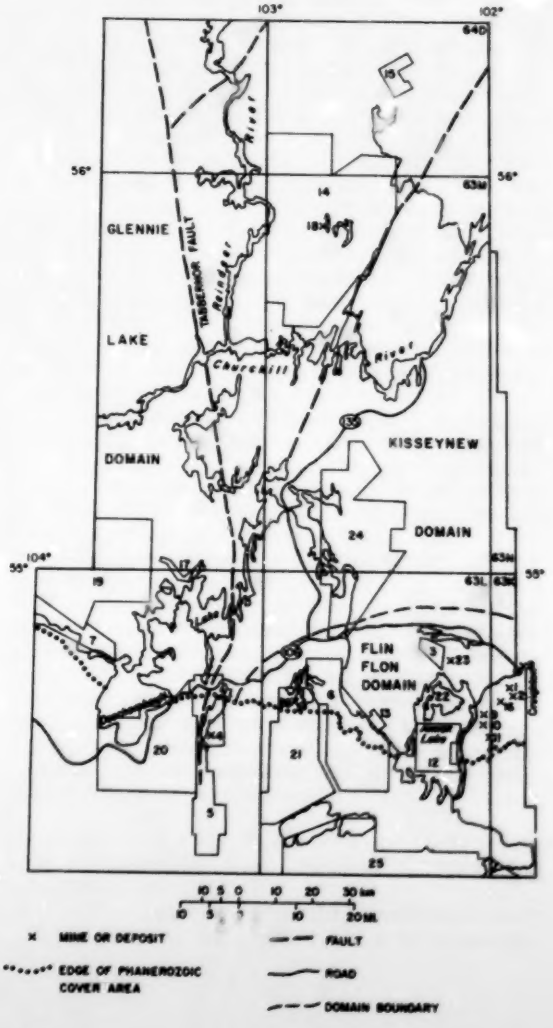

Figure 1 - Location of the southern part of the Reindeer Mining District showing present and past producing mines, deposits and areas of active exploration and development. Areas designated by operator of the project only: Flin Flon Mines Ltd., Newcor Mine Exploration AB (1), Rio Mine (2); Golden Rule Resources Ltd., Robinson Creek area (3); Granges Exploration AB, Bigstone Cu-Zn deposit (4), Limestone Lake area (5), Sturgeon-Weir River-Hanson Lake area (6), Oskikebuk River (7); Hudson Bay Exploration and Development Co. Ltd., Flin Flon Mine (8); Flexar Mine (9), Birch Lake Mine (10), Coronation Mine (11), Amisk Lake (12), Wolf Lake (13), Gilbert Lake-Pauline Lake permit (14), Kyaska Lake (15); Kenergy Resource Corp. Wekach Lake (16); A.L. Parres Ltd., Deschambault Lake (17), Mukoman Lake deposit (18); Carina Mineral Resources Corp., Brownell Lake permit (19); D. Polquin and P. Devesaux, Deschambault Lake permit (20); SMDC, Hanson Lake (21), Amisk Lake (22), Robinson Creek (23), Waskwei Lake (24), Suggi Lake (25); Western Nuclear Mines Ltd., Hanson Lake deposit (26).

diamond-drill program (16 holes and 12 wedge holes) to evaluate the Bigstone Cu-Zn zone discovered last year. Granges also drilled a 100 m hole to evaluate a conductor in the Neagle Lake area northwest of Amisk Lake.

The company acquired 845.73 km^2 (208,984 acres) in two permits in the Reindeer Mining District and 953.48 km^2 (235,610 acres) in two additional permits in the La Ronge Mining District. An airborne EM and magnetometer survey was flown on one of these permits (MPP 1138) in the Hanson Lake area. Work on the other permits, which follow the Oskikebuk volcanic belt into the Wapaweeka Lake area, consisted of ground evaluation of known conductors.

Hudson Bay Exploration and Development Co. Ltd. (HBED) carried out three base metal exploration projects during the year. In the Amisk-Errington-Wolf Lakes area, 177 km of linecutting, 150 km of Apex MaxMin II horizontal loop EM surveys, 154 km of magnetometer surveys and nine holes totalling 914.4 m were completed. In the Flin Flon area, there was a small geophysics and drill program comprising 6.4 km of magnetometer and MaxMin II EM survey and 163 m of diamond drilling, and at Gilbert-Pauline Lakes the company carried out an 11-hole, 840.3 m drilling program on MPP 1116 and 1117, together with 1.6 km of horizontal loop EM and 5 km of magnetometer surveying. Geological mapping and ground evaluation of other conductors on these permits and also on claim blocks in the Kyaska Lake area were undertaken during the summer.

A.L. Parres Ltd., in joint venture with Win-Eldrich Mines Ltd., completed 24.1 km of linecutting and horizontal loop EM and magnetometer surveys on three claim blocks in the Deschambault Lake area.

The Saskatchewan Mining Development Corporation (SMDC) had two base metal exploration projects in the Hanson Lake area. The winter project, on Paleozoic rocks south of Hanson Lake, consisted of 30 km of horizontal loop EM (Apex MaxMin II), VLF-EM and magnetometer surveys, and a five-hole diamond-drill program totalling 900 m. The summer project involved geological mapping of claim blocks in the immediate Hanson Lake area.

Gold

Flin Flon Mines Ltd. is currently constructing a 115 t/day (125 ton/day) mill and plan to begin production from the Rio Zone by December of 1983. Published reserves to the 107 m (350-foot) level are 998,000 t (110,000 tons) grading 7.89 to 13.03 g/t (0.23 to 0.38 oz/ton) Au. During the past year, Flin Flon Mines Ltd. carried out a development drilling program on the 23 m (75-foot) level and are planning development or fill-in drilling to complete the reserve picture to the 61 m (200-foot) level. A further deep drilling program is planned for the near future. Stockpiling of ore is being carried out until the mill goes into operation.

Golden Rule Resources Ltd. acquired a claim block in the Robinson Creek area north of Amisk Lake and carried out a prospecting and geological mapping program on this gold property.

Kenergy Resource Corp. undertook geophysics and sampling programs on the former Wekach Lake Gold Mines Ltd. property south of Creighton. During the winter, 3 km of linecutting, magnetometer, MaxMin II horizontal loop EM and VLF-EM surveys were completed around the location of the old shaft. Further work included dewatering of the 5 m shaft, stripping in the shaft area and detailed mapping and sampling of the shaft and the surrounding area.

SMDC has two separate gold exploration projects in the Amisk Lake area. At Robinson Creek, a SMDC-Suneva joint venture, SMDC became operator of the project and drilled six holes totalling 824 m to further evaluate previously identified gold zones. Drilling was followed by a program of detailed geological mapping as well as soil and basal till geochemical surveys.

In the West Channel area of Amisk Lake, SMDC completed a 19-hole, 3200 m diamond-drill program to evaluate the gold potential in this area. In addition, they also did detailed- and reconnaissance-scale geological mapping and soil and bedrock geochemistry on the property.

Activity of the Creighton Office

During the past year Saskatchewan Energy and Mines has acquired a core storage facility located at Denare Beach, 16 km west of Creighton. To date, core from one gold and several base metal deposits has been collected and made available for examination.

Mineral Exploration Activity in the Athabasca District

by D. J. Thomas

During 1982 the level of mineral exploration activity in the Athabasca Mining District remained low. Some exploration for unconformity-type uranium was carried out in the Stony Rapids and Black Lake areas by Eldor Resources Ltd. and Saskatchewan Mining Development Corporation (SMDC), while AMOK Ltd. maintained efforts in the Carswell-Cluff Lakes area. A small precious metals program was carried out by SMDC in the Beaverlodge area during the summer of 1982.

During the last 11 month period only one new mineral disposition totalling 0.16 km^2 (40 acres) was registered, compared to 25 dispositions totalling 1442 km^2 (356,193 acres) during the previous year. In the Athabasca Basin there was some reduction of claim blocks and conversion of mineral prospecting permits to claim blocks. A total of 14,433 km^2 (3,566,550 acres) lapsed during the same period, representing a 230 percent increase over the previous year.

Eldor Resources Ltd. (formerly Eldorado Nuclear Ltd.) continued their second year of decommissioning the Beaverlodge mine. Work to date has included dismantling of the mill and surface buildings, ongoing reclamation of the tailings system, and filling-in of open pits and adit portals. The Beaverlodge uranium mine, which had been in production since 1953, ceased operations on June 30, 1982 because of falling grades, depressed uranium prices and increasing production costs.

Cluff Mining, owned 80 percent by AMOK Ltd. and 20 percent by Saskatchewan Mining Development Corporation, submitted a proposal to the provincial government for Phase II development of the Cluff Lake operation. Phase II will involve mining and milling of uranium from the Claude, N, N40, OP and Dominique-Peter orebodies. Recoverable reserves are estimated at 14,000 tons of uranium which would yield about 15 million kg U_3O_8. Phase I mining of the D orebody commenced in May 1980 and was completed in September 1981. More than 60,000 tons of high-grade uranium ore were removed and stockpiled during this period, to meet Cluff Mining's uranium sales contracts to the end of 1984 (AMOK Ltd., 1982).

Exploration Activity

Eldor Resources Ltd. continued uranium exploration on their Stony Rapids Project, which comprises 16 claim blocks and 1 mineral lease held jointly with SMDC, by carrying out 1200 m of diamond drilling. Other Eldor Resources Ltd. uranium projects, including those at Pond du Lac (I and II), Maurice Bay-Lobstick Island and Fishook Bay (Thomas, 1981, 1982), remained dormant during the year.

SMDC operated one uranium and two precious metals projects in the Athabasca district. The Black Lake uranium project, a joint venture with Eldor Resources Ltd. and Power Reactor and Nuclear Development Co. (PNC), is situated on the northern margin of the Athabasca Basin in NTS quadrangles 74I-16 and 74P-1, -2 and -3. Work included line cutting, ground geophysics (magnetometer, MAX-MIN II, gravity and VLF-EM16 surveys) and 41 drillholes totalling 5000 m.

SMDC carried out precious metal projects at Lodge Bay and Dianne Lake. On the Lodge Bay gold property (NTS 74N-7; CBS 5664, 5665 and 5677), approximately 750 m of underground diamond drilling in the old Frontier adit was completed during the summer. In addition, detailed geological mapping and sampling, as well as a VLF and magnetometer survey were carried out over about 40 km of recently cut lines. The geology around the Frontier adit is described as a "sill-like mass of ... pink granite ... intruded into quartzite overlain by amphibolite" (Beck, 1959). Gold mineralization is intimately associated with pyritiferous phases of the granite and crosscutting quartz veins.

At Dianne Lake (NTS 74N-10), SMDC carried out an evaluation of silver-copper mineralization on CBS 3141, S-97735 and S-97736 (disposition holder Comaplex Resources International Ltd.). Native silver is associated with disseminated copper and cobalt arsenides along 'hairline' fractures which crosscut a foliated quartz monzonite-granodiorite body.

AMOK Ltd. continued exploration on their mineral dispositions in the Cluff-Carswell Lakes area (Table 1).

Table 1 - Summary of 1983 Exploration Activity in the Cluff-Carswell Lakes Area by AMOK Ltd./Ltee (Courtesy of AMOK Ltd./Ltee)

METHODS \ ZONE OF ACTIVITY 1983	sec. 5246	sec. 5247	sec. 5248	sec. 5249	sec. 5270	sec. 5271	✱ MISCELLANEOUS	TOTAL
RADON - Down hole				X				X
GEOCHEMISTRY								
U	1166		194	474	162	277	45	2268
B	1069		296	474	162	277	45	2272
Au				1				1
Cu			15					15
U, Pb				65				65
Cu, LOI			5					5
Cu, U, Pb, LOI	1		426					427
U, Pb, Cu, LOI, Fe, Mn, CO_2, Co				41				41
Whole rock	192		10			39	12	253
Multi elements	132		16			1	12	161
Clays (K, I, C)	1267		491	635	162	122	93	2770
P2 O5	5				17	16		38
Y, Zr	36					22		58 (8378) samples
GEOPHYSICS								
GRAVITY	108		64	92	24	19		1278 Lms/Km
SPECIFIC GRAVITY	1			5				6 holes
MAGN... II	449							449 Lms/Km
SPECIAL STUDIES								
GEOCHRONOLOGY	X		X	X				X
PETROGRAPHY	X		X	X		X		X
METALLOGENY	X			X				X
QUATERNARY GEOLOGY	X		X	X				X
TRENCHES	22		7	1				30
DRILLING								
Reconnaissance BQ, NQ	27635			688				34453 m
Evaluation, Percussion	1183							1183 m
BQ, NQ	5292							5292 m

✱ MISCELLANEOUS: Samples collected out of property for calibration.

Activities of the Uranium City Office

The district office in Uranium City was closed as of September 15, 1983 due to the decrease in exploration activity and the volume of services requested.

A bedrock sampling program, initiated in 1982 to establish a record of the mineral occurrences, deposits and other important geological features from the Athabasca Mining District, was completed in 1983. All material collected is presently stored and

catalogued at the Subsurface Geological Laboratory in Regina.

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SEDIMENTARY GEOLOGY INVESTIGATIONS

Biogeochemical Investigations in Northern Saskatchewan: Preliminary Data on Tungsten, Gold, Platinum, Rare Earths and Uranium

by Colin E. Dunn

I. OVERVIEW

The aims of the biogeochemical program are threefold:

1) To determine the distribution and concentrations of elements in common plant species in unmineralized areas, thus establishing background values; and near zones of known mineralization to determine whether anomalous values are detectable. As part of the study, consideration is given to metal uptake under a variety of environmental conditions and over a range of common rock types.
2) To investigate the use and usefulness of biogeochemical methods for mineral exploration on both regional and local scales.
3) To develop new exploration methods that are easy to undertake, rapid to perform and low in cost.

The overall intention is to provide an effective additional tool to an exploration program that above all must be practical, and which can be used in conjunction with other more traditional exploration methods. With the current state of the art, biogeochemistry should not and must not be used without careful consideration given to the geology, hydrogeology, soils, topography and any local environmental peculiarities such as the possibility of contamination by airborne material.

Studies conducted in 1983 consisted of three two-week periods, during which the author and one assistant visited areas of known uranium, gold, platinum and rare-earth element mineralization (Fig. 1). In each area sampling was extended from the mineralized areas into 'background' regions. Two of the studies (gold and uranium) were more regional in nature, and were conducted in an attempt to delineate relatively auriferous and uraniferous bedrock, respectively.

Included in the following accounts is a study conducted in 1982 over presumed tungsten mineralization. Data from this study became available early in 1983 and provided some basic information upon which the 1983 field program was developed.

A standard sample preparation procedure is now adopted for the vegetation analysis for most elements. This involves drying samples in a microwave oven to remove all moisture, followed by separation of leaves (or needles) from twigs. The separated plant organs are then placed in aluminum trays and ashed in a pottery kiln at 475°C for 24 hours. Unless stated otherwise all analyses quoted in the ensuing accounts are concentrations in ashed material prepared in the above manner.

II. TUNGSTEN

Studies have shown that plants can absorb moderately high concentrations of tungsten. Kovalevskii (1966) found tungsten to be concentrated in plants growing in a permafrost region of the USSR. Dekate (1967) found plants growing over a mineralized zone in India to contain 2 to 18 times as much tungsten as the background value of 2.7 ppm W. Quin et al. (1974) found up to 300 ppm W in the ash of beech trees growing over scheelite deposits in New Zealand. Further studies have shown encouraging results for tungsten prospecting using plants (Kovalevskii 1978), humus (Toverud, 1979), and plant saps (Zaguzin et al., 1981).

In the light of these results an area in northern Saskatchewan was chosen for study in order to determine which plant species (if any) accumulated tungsten.

Christie (1953, p. 115) reported that "a considerable amount of scheelite ($CaWO_4$)" was present in a radioactive occurrence known as the Radiore Zone No. C1 (Beck, 1969). Since no follow-up work on this discovery has been published, a few days were spent during July 1982 collecting soils, rocks and vegetation over the area. A brief account of the survey is given in Dunn (in press).

The occurrence lies 1.2 km south of the west end of Collier Lake, 10 km east of Uranium City (Fig. 1). Pitchblende occurs along an east-striking fault zone in quartz-feldspar-hornblende gneiss and in fractures striking 060° and 340°. Eldorado Nuclear Ltd. mined the occurrence for uranium in recent years. Examination of the pit, surrounding outcrop and drill core failed to locate any scheelite. A night survey of the area with

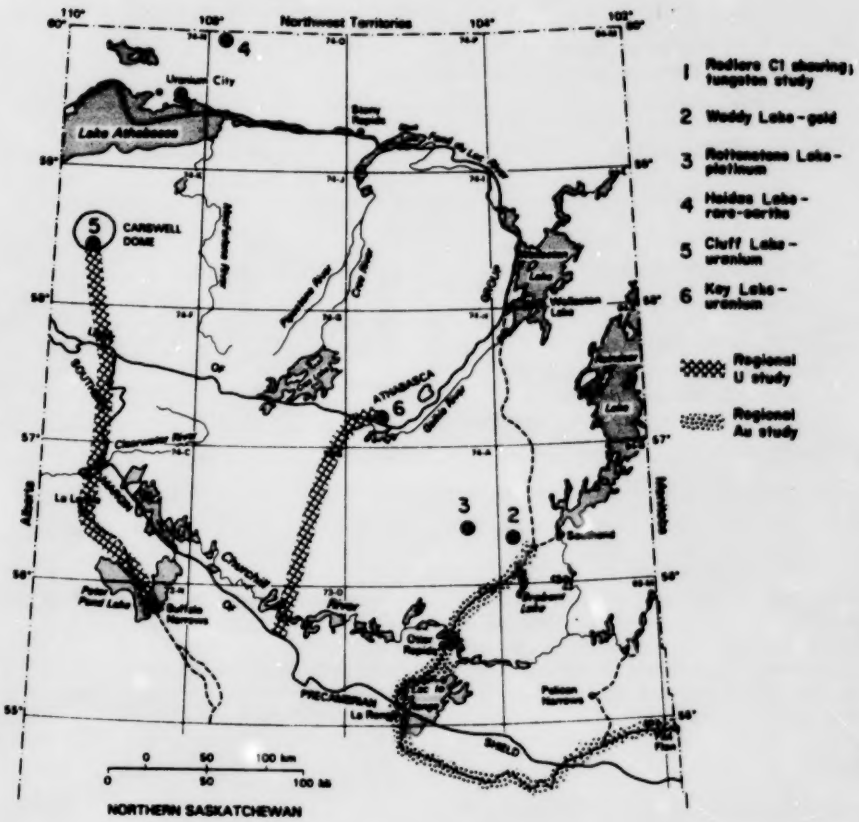

Figure 1 - Location map of areas studied.

an ultraviolet lamp showed some calcite fluorescence and spectacular green fluorescence of uranium minerals on joint planes, but no sign of the bluish-white fluorescence characteristic of scheelite. Thus the survey was restricted to the collection of samples from 33 sites over an area of 200 by 250 m.

A forest fire burned over part of the area approximately 12 years ago, so the forest is dominated by young jack pine (Pinus banksiana), birch (Betula sp.) and alder (Alnus sp.), with some black spruce (Picea mariana), labrador tea (Ledum groenlandicum) and juniper (Juniperus sp.). Immature podzols are present between outcrops of mildly radioactive gneisses.

Sixteen sample media were prepared by the procedures outlined in Section I (this paper), providing over 300 samples for analysis. Of these, 130 samples were selected for tungsten (W), gold (Au), uranium (U), arsenic (As), antimony (Sb), molybdenum (Mo) and samarium (Sm) analysis by neutron activation. This choice of elements was to provide background data on those that could be determined along with tungsten for low extra cost, and to help determine suitable sample media for the following year's research program.

Results

Tungsten

Table 1 summarizes the data obtained for W. Concentrations were close to normal background levels in all samples, and the mean W content of the rocks was 2 ppm (equal to the Clarke for this element). No single sample site yielded all the sample media considered in this study. However, it does appear from considering different permutations of samples that the twigs of black spruce, labrador tea and jack pine tend to concentrate W more strongly than all other plant parts (Table 1). Although no W mineralization was discovered, the biogeochemical survey has indicated the most

Table 1 - Tungsten in Rocks and Vegetation from the Vicinity of a Reported Scheelite ($CaWO_4$) Showing in the Radiore C1 Uranium Zone, 10 km east of Uranium City (130 Samples Comprising 16 Sample Media)

Sample Medium	n	Tungsten (ppm)	
		Range	Mean
Rocks (granitic gneiss)	21	<.7 - 6.7	2.0
Twigs (black spruce)	13	<.7 - 3.5	2.0
Twigs (labrador tea)	4	<.7 - 3.9	1.7
Twigs (jack pine)	5	<.7 - 2.0	.7
Needles and leaves of above and all leaves and twigs of alder, birch, willow, juniper	78	<.7 - 1.0	<.7
B_F horizon soils (-80 mesh)	9	<.7 - 0.8	<.7

suitable sample media for a W survey in this environment. Consideration should also be given to the trunks of the trees (cf. Quin et al., 1974); however, few trees in the study area were sufficiently mature to test the W uptake of the tree trunks.

Other elements

Table 2 shows the maximum values obtained for each sample medium, and gives a broad guide as to the relative sensitivity of the plants to the presence of several elements. In view of the erratic distribution of some plant species, and the low populations of other species, it must be emphasized that these preliminary data serve only as a crude indication of the plants' abilities to accumulate elements. Noteworthy concentrations are Au and Mo in alder, and U in twigs of spruce and jack pine. The unusually high U concentrations are attributed to the presence of readily leachable uranium in the joints and fractures. Spruce twigs appear more effective at concentrating As, Sb and Sm than the other sample media.

III. GOLD

Studies have shown that gold is absorbed by many plants (see review article by Boyle, 1979). Impressive case histories of successful biogeochemical surveys for gold by Baker (Tasmania), Curtin and King (USA), Erdman (USA), Riese and Arp (USA), and Hoffman and Brooker (Canada), amongst others, were presented at a recent symposium in Los Angeles and are currently in press (Carlisle et al., in press).

Studies in Saskatchewan indicate that gold is concentrated in forest litter near gold mineralization (Dunn, 1980), and is preferentially absorbed by alder (Alnus rugosa) in the Uranium City area (see Section II, this paper).

These results inspired the initiation of a regional biogeochemical survey for gold in an attempt to delineate relatively auriferous areas which could subsequently be investigated in greater detail. During the course of other surveys during May 1983, alder twigs were collected at 20 sites (some near known gold mineralization and others at presumed 'background' sites). This group of samples comprised the material for a small-scale orientation survey. At each site, the most recent 50 cm of alder twig growth was collected, generally representing 2 to 3 years growth. Since the survey was conducted in May, no leaves had sprouted. All samples were dried, a split ashed, and analyses done separately by neutron activation on dried and ashed material. All ashed samples were analyzed for Au and As, and selected samples of dried material were analyzed for Au, As and Sb. Many replicates and standards were inserted with each batch of samples submitted for analysis, and they attest to the excellent precision and accuracy obtained. Results show that no Au volatilized during ashing, because data corresponded closely after recalculating the data back to a dry weight basis.

Table 2 - Maximum Concentrations of Elements in Rocks, Soils and Ashed Vegetation from the Vicinity of the Radiore C1 Uranium Zone, 10 km east of Uranium City

Sample Medium	n	Maximum Concentrations[1]					
		U (ppm)	As (ppm)	Au (ppb)	Mo (ppm)	Sb (ppm)	Sm (ppm)
Rocks	21	0.5-28[2]	3.3	< 20	3	.8	12.0
A_0 soil	27	1.9-19	NA[3]	NA	NA	NA	NA
B_1 soil	9	1.7-4.3	2.0	< 20	< 2	< .2	3.6
Spruce twigs	13	75-291	4.1	< 20	< 10	1.2	7.1
Spruce needles	14	2-25	1.1	< 20	< 8	.3	.8
Alder twigs	25	1-33	.2	60	274	.8	3.2
Alder leaves	25	0.5-15	.7	200	146	.6	2.6
Jack pine twigs	5	30-147	2.0	60	< 10	1.0	2.3
Jack pine needles	5	7-47	.9	20	28	.9	1.3
Birch twigs	7	11-99	1.5	50	< 2	< .2	1.6
Birch needles	7	0.9-9	.9	20	< 2	.4	< .2
Lab. tea twigs	4	7-56	1.7	70	14	1.1	2.5
Lab. tea leaves	4	4-11	1.2	40	7	< .2	.5
Juniper twigs	2	14 & 20	< .3	< 20	< 10	.3	.8
Juniper leaves	2	7 & 16	< .3	< 20	52	.3	.4
Willow twigs	2	1.7 & 2.7	< .3	< 20	24	< .2	1.4
Willow leaves	2	0.7 & 1.5	< .3	< 20	24	.3	.9

[1]Except for uranium, the lowest concentration of elements in all sample media was below detection limit (i.e. approximately 0.3 ppm As, 20 ppb Au, 2 ppm Mo, 0.2 ppm Sb and 0.2 ppm Sm).
[2]Values from surface outcrop; samples from the pit that was mined for uranium yielded up to 4680 ppm U.
[3]NA = not analyzed

Arsenic concentrations in ashed samples ranged from 0.2 to 6.7 ppm, but did not show a consistent pattern of enhanced values where Au levels were higher. In the dried samples As ranged from 0.02 to 0.34 ppm and Sb from < 0.01 to 0.04 ppm. It appears that little or no As was lost during ashing. It was anticipated that Sb would volatilize, so ashed samples were not analyzed for this element.

Results

Orientation Survey

Table 3 summarizes the concentrations of Au found in ashed alder twigs. The data show that, in the Cluff Lake (Carswell Structure) and Box granite (Uranium City) vicinities (Fig. 1), the mean Au concentrations are appreciably higher than in the other three test areas. The wide range of concentrations observed in each area is attributed to the random sampling and the local concentrations of Au. At Cluff Lake two samples were from soils known to contain Au. In the Box granite area samples were not collected from near the disused Box Mine (Au) but rather from around a nearby lake (Vic Lake) without knowledge of the bedrock Au content at each site. A sample of forest litter from beneath one alder at Cluff Lake had in its ash less than half the Au content of the ashed twigs.

Cones from one alder contained more Au than twigs of the same shrub, yet at another site the opposite occurred. Unashed samples of cones and twigs returned very similar values.

Table 3 - Gold Concentrations in Ashed Twigs of Alder (Alnus rugosa), Orientation Survey, May 1983 (Random Sampling)

Location	n	Gold (ppb)	
		Range	Mean
Cluff Lake area (auriferous soils)	4	25-386	152
Box granite (auriferous bedrock)	6	17-217	79
Key Lake Road	3	9-55	38
Anglo-Rouyn copper mine	6	7-29	17
South of La Ronge (above Cretaceous Sandstones)	1		15

Regional Survey

The above orientation survey was sufficient to show a positive response of Au uptake by alder twigs in areas of known mineralization, and encouraged a program of more widespread sampling during a seven-day period in early August.

Alder samples were collected about 50 m from the roadside at 2 km intervals from Lac la Ronge to Brabant Lake (Fig. 1). Black spruce twigs were collected at every second site (4 km), since spruce also shows a tendency to concentrate Au. Data on these samples are not yet available. From Brabant Lake the sampling interval was reduced to 1 km for 18 km northwestward to the Komis Au deposit by Waddy Lake. Detailed sampling was conducted in the vicinity of the Komis mineralization.

In addition, samples were collected at 20 km intervals eastward from La Ronge across Cretaceous sandstones and Ordovician carbonates to the Precambrian terrain near Flin Flon, and over known Au mineralization in that area. The 176 sites visited provided about 240 samples which (when separated into leaves, twigs, etc.) produced nearly 500 samples for analysis. To date, Au and As values have been received for 100 samples.

Fig. 2 shows the regional distribution of Au in ashed alder twigs sampled from the northern end of Lac la Ronge, across to Stanley Mission and northward past Otter Lake. The most striking feature is the consistently high Au concentrations, from 20 to 130 ppb, that occur in the Glennie Lake Domain. Samples from the La Ronge Domain rarely yield more than 10 ppb Au. The reason for this is unknown, but two possibilities are offered. Either:

1) the extensively sheared Glennie Lake Domain is generally more auriferous than the La Ronge Domain; certainly numerous Au showings are known just north of Lac la Ronge; or
2) the traces of Au within the Glennie Lake Domain are present in a form (in the bedrock or soils) that is more readily accessible to absorption by the alder roots than in the La Ronge Domain.

Further investigation seems warranted.

Samples collected in the vicinity of the Komis Au deposit yield much lower Au concentrations than expected. Table 4 shows Au in bedrock, various size fractions of soil, and several parts of alder shrubs rooted at these two sites. Arsenic was at or below the detection limit of 1 ppm in all vegetation samples; its content in the bedrock was not determined. The Au content of the granodiorite, from within a few centimetres of the andesite, is surprisingly high (3600 ppb), and there is a marked tendency for Au to concentrate in the coarse fraction of the soils. The high Au content of the forest litter is considered to be mainly contained in adhering soil particles rather than the organic debris. This conclusion is supported by the high Au content of a gritty sample of forest litter from site A. Clearly the alders are showing very little tendency to absorb the abundance of Au present in the bedrock and soils. Perhaps this is due to the inorganic nature of the soils, and the lack of organic acids normally available in the humus layer to aid in mobilizing Au and transporting it into the plants; a few years ago the outcrop was washed clean, and the sparse vegetation has not had time to add an appreciable organic fraction to the new mechanically derived soil. It seems that careful consideration should be given to the nature and maturity of the soil when interpreting Au biogeochemical data.

Two alder samples collected from the vicinity of the Rio Au occurrence near Flin Flon contained 25 and 45 ppb Au in their twigs, and 20 and 65 ppb in the leaves. Arsenic contents ranged from 9 to 17 ppm. Another Au occurrence in the vicinity of Wekach Lake near Flin Flon yielded 65 and 230 ppb Au in alder twigs, and 85 and 160 ppb in the leaves. In general, studies showed that the Au content of leaf ash in August was slightly lower than that of twig ash. Preliminary results suggest that during the growing season the Au content of twigs increases, whilst that of the leaves decreases.

The potential use of alder twigs in delineating auriferous zones seems promising, provided careful consideration is given to the soils in which they are growing. The latest 50 cm of twig growth appears to be a practical amount to collect.

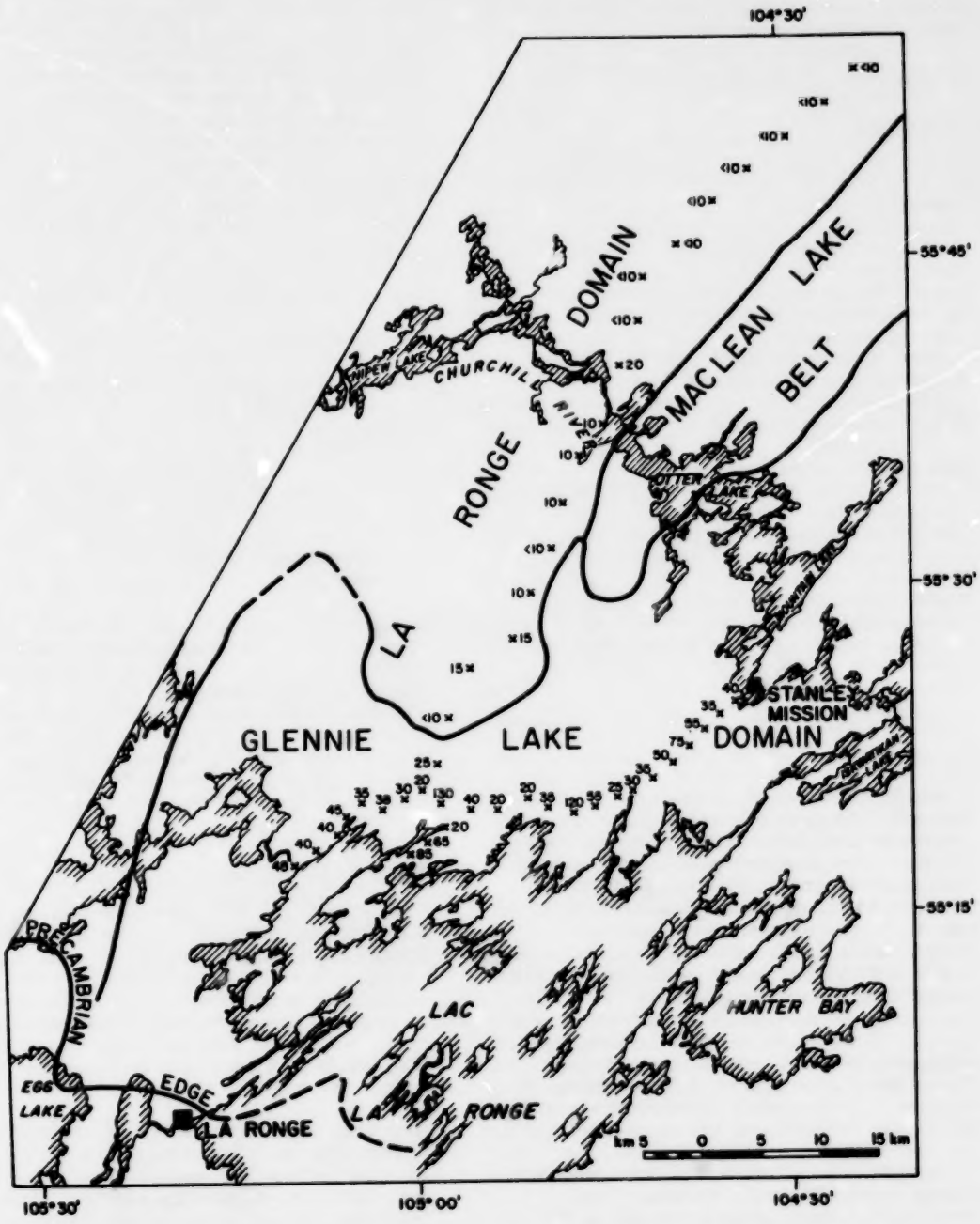

Figure 2 - Distribution of gold in the ash of alder twigs (ppb).

Table 4 - Gold Content of Bedrock, Soils, Forest Litter and Alder Shrubs Rooted in a Fracture in Andesite, Adjacent to a Pluton of Granodiorite, Komis Deposit, Waddy Lake; Alder at Site A was 1.5 m High, That at Site B was 1.0 m High

Sample Medium	Au (ppb)	
	Site A	Site B
Andesite	950	1220
Granodiorite	-	3600
Soil (-10 to -40 mesh)	910	4700
Soil (-40 to -80 ")	500	2600
Soil (-80 to -200 ")	290	1550
Soil (less than -200 mesh)	405	1100
Forest litter	250	410
Forest litter (gritty)	1500	-
Alder twigs (latest 50 cm growth)	20	20
Alder leaves (on latest 50 cm growth)	10	<10
Alder twigs (growth from 50 to 100 cm from tip of twig)	35	35
Alder leaves (on growth from 50 to 100 cm from tip of twig)	25	-
Alder stems (growth from 100 to 150 cm from tip of twig)	<10	-
Alder twigs (dead)	15	-
Alder stems (dead)	35	-

IV. PLATINUM

A search of the world literature indicates that the only publication on platinum biogeochemistry is that by Fuchs and Rose (1974). They analyzed the ash of twigs from four trees in the Stillwater Complex of Montana and found concentrations of 12 to 56 ppb Pt. A presentation at a symposium in Los Angeles (Feb. 1983) entitled "Organic Matter, Biological Systems and Mineral Exploration" showed that plants growing over the platiniferous Marensky Reef in South Africa contain up to 1500 ppb Pt in dry leaves (P.J. Petersen); a second study (Riese and Arp, in press) found 3000 ppb Pt in ashed twigs of Douglas Fir above platiniferous zones in the Stillwater Complex.

In Saskatchewan platinum has been recorded from several ultramafic bodies. Two occurrences, Rottenstone (Fig. 1), and Nicholson near Uranium City, were selected as biogeochemical test sites to determine the distribution of Pt, Pd and Au in a variety of common plants. Data from the Rottenstone area are reported here.

The Rottenstone Deposit

The Rottenstone Lake (Hall showing) Ni-Cu-Pt-Pd deposit consists of about 50 percent sulphides disseminated in a body of pyroxene-rich rock that is surrounded by gneissose metasediments (Richards and Robinson, 1966). According to these authors the body has an average thickness of 8 m and dips 30° to the east, rising as far above the average land surface as it does below it. It has been surmised that the pyroxenite body occurs as a raft (i.e. a roof pendant) within the migmatitic complex (cf. Gilboy, 1975). The sulphides are mainly pyrrhotite (FeS), violarite (Ni_2FeS_4) and chalcopyrite ($CuFeS_2$). Platinum occurs as minute grains of sperrylite ($PtAs_2$).

The deposit was mined from 1965 until the ore was exhausted in 1968. Thus, 15 years have elapsed during which the vegetation could become re-established.

Three days at the end of May were spent in the area collecting vegetation and bedrock from 22 sites in the vicinity of the worked-out deposit and two sites on a mineralized zone of similar appearance (the Tremblay-Olsen showing), 2.5 km to the southwest.

Samples were collected at intervals of approximately 100 m along four lines spaced 200 m apart (Fig. 3). Twigs of black spruce (Picea mariana) were collected at all sites (latest ten years of growth). In addition, labrador tea (Ledum groenlandicum), jack pine (Pinus banksiana), shrub alder (Alnus sp.), willow (Salix sp.) and birch (Betula sp.) were collected at selected sites.

Preliminary Results

Six boulders of ore-grade rock were analyzed for precious metals to provide a general comparison with the vegetation samples. It should be noted, however, that no vegetation sample was found rooted in or close to a boulder of high-grade ore. Concentrations in those rocks were 1200 to 3600 ppb Pt, 3500 to 6900 ppb Pd, 20 to 67 ppb Rh, and 210 to 340 ppb Au.

Data have been received for Pt, Pd and Au concentrations in all samples of spruce twigs (n = 24) and spruce needles (n = 24). One analysis is available for each of labrador tea twigs, birch twigs, willow twigs and spruce trunk. Table 5 shows the concentrations in these species from a single locality, thereby permitting direct comparison of the relative uptake of the

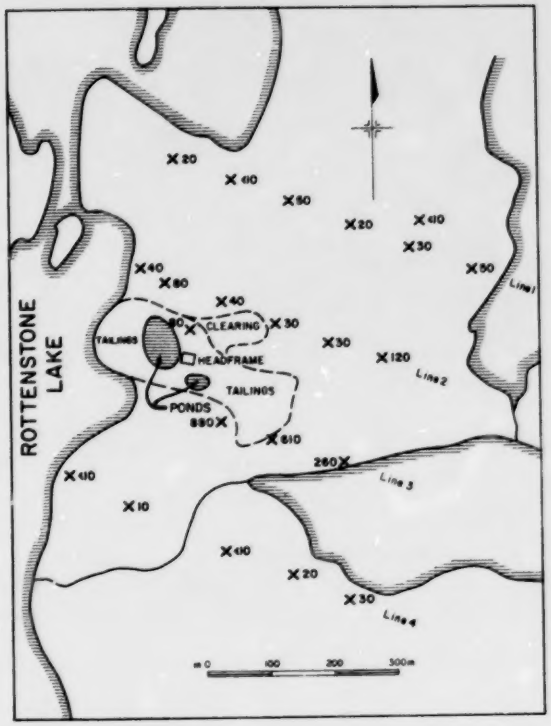

Figure 3 - Sketch map of platinum (ppb) in the ash of black spruce twigs, Rottenstone mine area.

precious metals by the plants. Clearly, the black spruce and labrador tea twigs, and jack pine trunk are more effective at concentrating Pt and Pd than the other plant parts. The high concentration of Au in the spruce trunk is of interest and worth further investigation.

Table 5 - Concentrations of Platinum, Palladium and Gold in Plants from a Test Site on Disturbed Ground Above the Worked-out Rottenstone Mine. All Samples from Within a 5 by 5 m Area.

	Pt (ppb)	Pd (ppb)	Au (ppb)
Black spruce twigs	80	120	9
Black spruce needles	10	10	<2
Black spruce trunk	70	62	460
Jack pine twigs	50	52	62
Jack pine needles	20	17	<2
Jack pine trunk	70	120	23
Labrador tea stems	80	170	60
Birch twigs	<10	7	18
Willow twigs	<10	3	<2

High concentrations of precious metals are present in the twigs of black spruce growing down drainage from the tailings debris (line 3 on Figs. 3, 4 and 5). In addition there are fairly high values of Pt and Pd on the ridge that occurs immediately north of the old mine (line 2), and at two sites along line 1 where Pt concentrations are 50 ppb. Gold values are only anomalous at two sites north of the mine, where 68 and 76 ppb Au are recorded along line 1. It appears that background values in the spruce twigs are about 2 ppb Au, 10 ppb Pt and 10 ppb Pd.

The biogeochemical results are encouraging since they indicate that in this heavily forested terrain it may be possible to use the vegetation to provide a 'window' through the glacial cover in order to assess the precious metal potential of the underlying bedrock.

V. RARE-EARTH ELEMENTS (REE)

Near Hoidas (previously known as Lane Lake) and Nisikkatch Lakes in northernmost Saskatchewan (Fig. 1), high concentrations of REE (locally 12 percent) occur in several outcrops of radioactive allanite (Hogarth, 1957). The country rock is predominately pink granulite and felsic gneiss containing variable amounts of biotite and amphibole. The allanite occurrences are erratically distributed over a distance of 10 km, but are associated with zones of fracturing and shattering that conform to the regional strike of about 045°. Associated with the allanite are apatite, carbonate (calcite and barite), hyalophane (Ba-feldspar) and amphibole. The radioactivity of the allanite is due to thorium (up to 4000 ppm); uranium concentrations are generally about 50 to 100 ppm.

In trying to define the extent of the mineralization, the radioactive component of the rocks has been a useful guide to near-surface outcrop. Background scintillometer counts are 20 to 30 cps; over most outcrops counts are 60 to 120 cps, rising to 2000 cps in trenches above rich mineralization at the south end of Hoidas Lake. However, the radioactivity of the allanite is variable, making exploration difficult for possible mineralization beneath muskegs, soils and glacial cover. Cliff faces have been blasted in recent years in an attempt to uncover mineralization, but inspection of these fresh surfaces shows only small blebs of allanite with halos of radiation-damaged minerals.

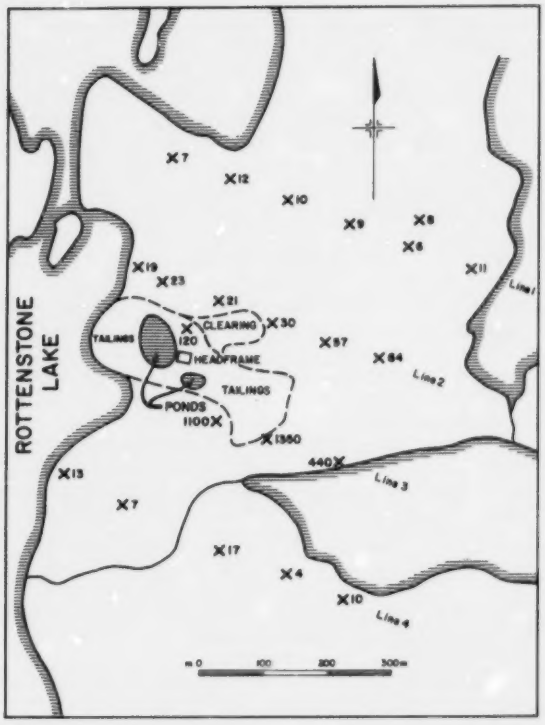

Figure 4 - Sketch map of palladium (ppb) in the ash of black spruce twigs, Rottenstone mine area.

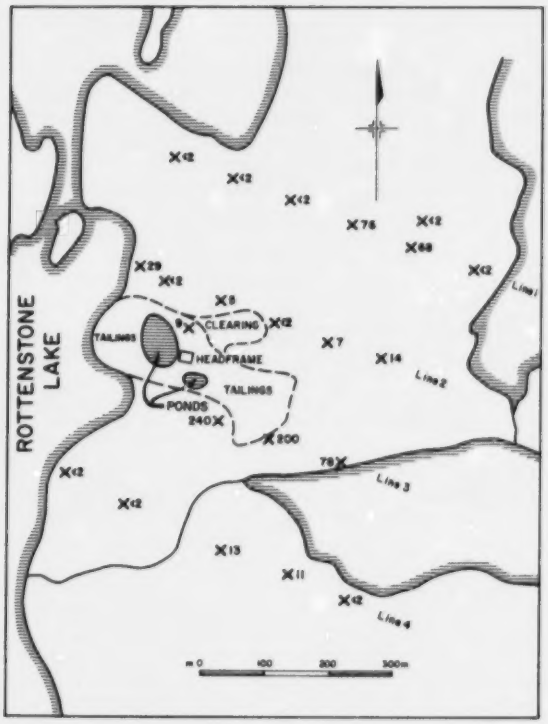

Figure 5 - Sketch map of gold (ppb) in the ash of black spruce twigs, Rottenstone mine area.

The vegetation is a possible medium that may aid in outlining mineralization in the area. It was shown long ago that some plants are capable of concentrating the rare-earths (Robinson et al., 1938). Studies of vegetation growing above REE-rich pegmatites in Finland have indicated that mosses and lichens can concentrate REE, but the uptake by trees is relatively low (Yliruokanen 1975). No studies have been made on the uptake by plants of metals from the Hoidas Lake type of mineralization, so during a five-day period in mid-June of 1983 a biogeochemical orientation survey was made of the Hoidas Lake zones of mineralization. The purpose was to determine which parts of the common species were most sensitive to this type of mineralization, and to ascertain if any biogeochemical sample medium might be used as an aid to exploration. An additional reason for choosing this area was that it provided a test site with a wide range of elements, hence was suitable for examining the relative uptake of many elements into a variety of plants.

Earlier studies (see Section II, this paper) indicated that the twigs of black spruce have a tendency to collect samarium. In light of this observation, and the chemical coherency of the REE, black spruce twigs (latest 10 years growth) were collected at all sites. At selected sites additional samples included spruce trunk and cones; birch trunk, bark, twigs and leaves; labrador tea twigs, leaves and roots; willow twigs and leaves; alder twigs and leaves; jack pine twigs, bark, trunk and cones; and moss.

Samples were collected at 60 sites, providing about 240 samples for analysis following the sample preparation procedure outlined in Section I (this paper). Most samples were from dry flat woodland in the vicinity of a series of allanite outcrops near the north end of Hoidas Lake (Fig. 6). Ten lines normal to the strike of the mineralization were sampled. Lines were 25 m apart and the sample interval along each line was 20 m.

The "Rare earth mineral exploration package" offered by Nuclear Activation Services Ltd. was chosen as the most suitable and cost-effective method of analysis for this study. This package offers neutron activation analysis for the rare-earth

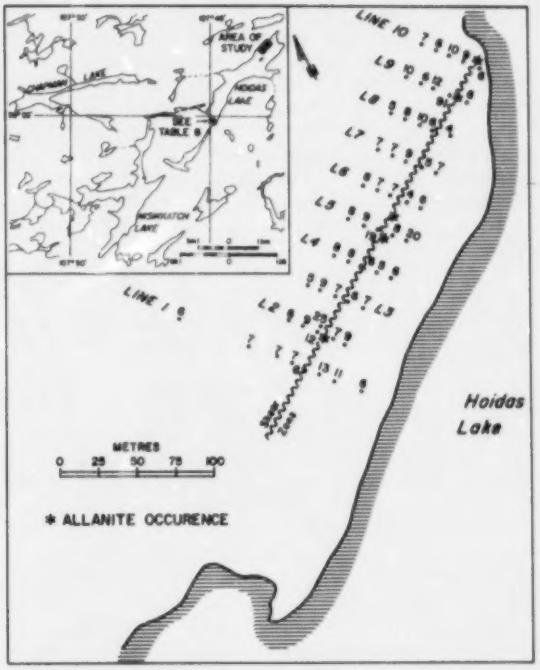

Figure 6 - Lanthanum (ppm) in the ash of black spruce twigs, allanite mineralization at north end of Hoidas Lake.

elements lanthanum (La), cerium (Ce), samarium (Sm) and lutetium (Lu). This suite of elements is sufficient to obtain a broad indication of the ability of the plants to accumulate the 15 elements which comprise the rare-earths. In addition scandium (Sc), thorium (Th) and uranium (U) analyses were obtained. At a later date analyses will be available for Eu, Yb, Br, Au, Rb, Ba, Cs, Sr, As, Sb, Mo, Zn, Ta, Na, K, Ca, Cr, Fe, Co, Ni, Hf and W. Some of these may be useful pathfinder elements for the type of mineralization under investigation.

Results

Analysis of the allanite shows that it contains up to 6 percent La, 5 percent Ce, 0.3 percent Sm, but only 6 ppm Lu. In addition to the Th and U mentioned above, there is up to 2 percent Ba, 0.7 percent Sr and 800 ppm Pb.

The sensitivity of the black spruce twigs to the presence of REE is low. Fig. 6 shows that La concentrations are 6 to 8 ppm, except within a few metres of allanite outcrop where concentrations are 2 to 3 times this value and in one case reach 91 ppm La (Ce and Sm concentrations of this sample were correspondingly high). Cerium concentrations are generally 50 percent higher than La, whereas Sm is commonly below 1 ppm. Thorium values are consistently low (less than 3 ppm) and show no tendency for enrichment. Similarly, U concentrations rarely exceed 1 ppm, indicating that no readily leachable U is accessible to the plants.

Table 6 shows the concentrations of some elements in the ash of black spruce twigs and needles collected along line 5 (Fig. 6). The scintillometer reading taken at the base of each tree trunk is given for comparison,

Table 6 - Concentrations of Elements in the Latest 10 Years Growth of Ashed Black Spruce (Picea mariana) Twigs and Needles, Profile (Line 5 on Fig. 6) across Zone of Massive Radioactive Allanite (Located at Sample Site No. 27), Northwest End of Hoidas Lake

Site No.	Scint. Reading (cps)	Element Concentration (ppm)													
		U		Th		Sc		La		Ce		Sm		Lu	
		T[1]	N[1]	T	N	T	N	T	N	T	N	T	N	T	N
25	26	1.2	.1	2.9	<.5	2.3	<.5	20	2.8	31	5	1.6	.2	.07	<.02
26	29	1.3	.1	1.8	<.5	2.0	<.5	8	0.5	14	<1	1.0	.1	.09	<.02
27	60	1.0	.1	2.1	<.5	1.2	<.5	19	3.3	28	5	1.1	.2	.05	<.02
28	120	2.3	.1	2.1	.8	1.8	<.5	9	1.0	16	3	1.5	.3	.06	.02
29	26	2.3	.1	1.9	<.5	2.4	<.5	9	0.9	15	3	1.0	.1	.05	<.02
R28[2]	55	1.2		6		ND		47		ND		ND		ND	

[1] T = twig; N = needle
[2] Felsic granulite collected 30 cm from tree site no. 28.
ND = not determined

along with the U, Th and La concentrations of a rock from the most radioactive site (no. 28). The table shows that the twigs contain consistently higher concentrations of each element than the corresponding needles. The U and Th show no clear response to increased radioactivity, although a trace more Th is present in the needles at site 28. It should be noted also that the surface rock from this site (R28) does not have anomalous concentrations of U and Th. The tree at site 27 was growing 2 m away from a trench containing massive allanite. Again Th and U values are not enhanced, but both La and Ce values are elevated (in twigs and needles). However, at site 25 similar concentrations are present in twigs from a malformed tree. It is not known if these values are due to the presence of allanite near the roots of that tree, or to some other factor. In view of the generally elevated REE values in spruce twigs near allanite occurrences (Fig. 6), it seems possible that allanite may be present at this site.

The above indicates that the spruce twigs do show a weak response to allanite mineralization. However, analysis of other vegetation shows that the spruce is not the most sensitive sample medium for this type of mineralization. At site 27 twelve additional "bio-objects" (to use the term of Kovalevskii, 1979) were analyzed, and the resulting data (Table 7) clearly show that birch and labrador tea accumulate much greater concentrations of REE than spruce. The same is true of the willow and moss, but their environment was different from the other species in that they were growing in an old trench into allanite; the willow was a young shrub (50 cm high), and the moss that encrusted the rocks was thoroughly washed but could have retained some small inorganic particles. Similarly, the high values obtained from the labrador tea roots may be in part due to adhering soil particles. An important aspect of the data in the table is that the trunks (stripped of bark) of both the spruce and birch gave relatively high REE values, indicating that the REE enter the trees via the roots and are not the result of airborne dust adhering to the plant surfaces.

To provide a comparison with site 27, data are given in Table 8 for plants collected above a rich occurrence of allanite on the top of a hill at the south end of Hoidas Lake. The plants were collected from a site about 10 m in diameter, within which radioactivity varied from 100 to 540 cps at the base of the plants. The data show that, unlike site 27, there is not much difference in the concentrations of REE in spruce and birch, but jack pine and especially alder have much greater concentrations. The trunks of the spruce, birch and jack pine have high concentrations of REE, thereby confirming the observation at site 27 that the elements are absorbed internally, not externally.

Table 7 - Concentrations of Elements in Plants Growing Within 5 m of a Trenched Occurrence of Massive Radioactive Allanite (Associated with Hyalophane and Apatite), Site No. 27, Northwest End of Hoidas Lake

Description	Element Concentration (ppm)						
	U	Th	Sc	La	Ce	Sm	Lu
Spruce twig	1.0	2.1	1.2	19	28	1.1	.05
Spruce twig (top of tree)	1.3	1.6	1.4	21	28	1.3	.03
Spruce needle	0.1	<0.5	0.1	3	5	0.2	<.02
Spruce trunk	0.1	2.2	0.2	39	37	1.0	<.02
Spruce bark	0.2	0.9	0.2	24	30	1.1	.02
Birch twigs	0.4	<0.5	0.3	182	117	5.5	.02
Birch leaf	0.1	3.5	0.3	37	39	2.4	.02
Birch bark (outer)	1.0	14	1.1	102	189	6.6	.08
Birch bark (inner)	0.1	2.5	0.1	27	23	0.9	<.01
Birch trunk	0.3	<0.5	0.1	142	98	4.8	.02
Labrador Tea twig	2.8	2.3	0.7	194	227	8.3	.04
Labrador Tea root	3.9	4.7	0.7	139	170	7.3	.04
Willow twig	0.2	0.7	0.2	142	123	4.0	.04
Moss	19	14	1.1	820	1000	52	.11

Table 8 - Concentrations of Elements in Plants Growing Above an Outcrop of Massive Radioactive Allanite, South End of Hoidas Lake

Description	Scint. Reading (cps)	Element Concentration (ppm)						
		U	Th	Sc	La	Ce	Sm	Lu
Birch twig	400	0.1	2.0	0.1	56	40	2.0	<.02
Birch leaf	400	0.2	1.1	0.2	14	19	0.9	.03
Birch bark	400	0.3	2.4	0.1	33	39	2.0	<.01
Birch trunk	400	0.3	<0.5	<0.1	75	42	2.3	.02
Labrador tea root	540	0.8	4.4	0.9	67	97	6.2	<.04
Labrador tea stem	540	0.7	2.2	0.8	15	25	1.3	.05
Alder twig	540	0.3	<0.5	0.3	353	360	13	.03
Alder leaf	540	1.1	2.1	0.7	275	311	22	.06
Alder leaf (duplicate)	540	1.2	1.7	0.6	278	325	22	.06
Spruce twig	100	1.1	2.4	1.7	50	65	2.9	.06
Spruce twig (top of tree)	100	1.1	1.7	1.4	43	60	2.5	.06
Spruce Bark	100	0.2	0.9	0.2	24	30	1.1	.02
Spruce trunk	100	0.3	0.8	0.1	105	109	2.7	<.02
Spruce cones	100	0.9	2.6	0.8	10	18	0.9	.03
Spruce twig (young tree growing in trench)	400	1.1	2.9	1.3	84	118	4.7	.04
Jack-pine twig	200	0.8	0.8	0.9	138	142	3.7	.03
Jack pine needles	200	0.4	0.4	0.3	60	81	4.1	.02
Jack pine trunk	200	<0.1	<0.5	0.1	276	250	5.2	.03
Jack pine bark	200	0.2	1.0	0.1	178	165	4.4	<.02
Jack pine cone	200	1.1	2.5	1.0	17	26	1.4	.03

Conclusions

The thorium- and rare-earth-rich allanite mineralization in the vicinity of Hoidas Lake is reflected in the vegetation as follows:

1) Thorium concentrations up to 4000 ppm in bedrock show no enrichment in any biogeochemical sample medium. Uranium concentrations of 50 to 100 ppm that are typical for the allanite (with 2 ppm U in surrounding rocks) show no tendency to be absorbed by the plants. The uranium must be structurally bound into the crystal lattices and not readily leached, and is therefore not available for uptake by plant roots.

2) Lanthanum and cerium concentrations in ashed twigs of black spruce above felsic granulites are generally about 6 to 8 ppm and 10 to 12 ppm, respectively. Concentrations of 2 to 3 times these levels occur in the immediate vicinities of allanite mineralization near the north end of Hoidas Lake; however, above mineralization at the south end of Hoidas Lake concentrations are considerably higher.

3) Twigs concentrate rare-earths appreciably more than the needles in all species studied.

4) Tree trunks tend to concentrate the rare-earths, whereas cones tend to be depleted relative to the rest of the tree.

5) Highest rare-earth concentrations were found in a moss and labrador tea roots (both of which may have had adhering inorganic particles), and the leaves and twigs of alder.

6) Samarium enrichment generally follows that of La and Ce, but lutetium shows very little geochemical relief. This indicates that the plants perform a natural fractionation of the rare-earth elements.

7) It is considered that plants may provide useful information to aid in the exploration for rare-earth elements associated with the type of mineralization occurring in the Hoidas Lake area. Only one rare-earth (La or Ce) need be sought. It is unfortunate that alder is uncommon in this environment, since it appears to accumulate the rare-earths more than other species. The trunks of spruce, jack pine and birch contain relatively high concentrations, although twigs of spruce or birch are more practical to

collect. Enhanced values of rare-earths in the plants can only be expected within a few metres of mineralization. Investigation of associated elements may reveal pathfinder elements with much larger dispersion halos.

VI. URANIUM

Regional studies of the distribution of uranium in plants throughout northern Saskatchewan have revealed a large biogeochemical anomaly near Wollaston Lake, and anomalous concentrations in the Uranium City and Cluff Lake areas (Dunn, 1981, 1982a, b).

During late May these studies were extended to include the areas 1) around Uranium City in northern Saskatchewan, 2) from Buffalo Narrows to Cluff Lake in northwestern Saskatchewan and 3) from Pinehouse to Key Lake in north-central Saskatchewan. Results from these traverses are plotted on Fig. 7, and those from another traverse, from La Ronge to Southend, will be available at a later date.

The data represent U concentrations in the ash of the latest ten years growth of black spruce (Picea mariana) twigs. Northward from Buffalo Narrows rocks beneath the glacial till are Cretaceous sands and sandstones, which overlap sandstones of the Athabasca Group at about latitude 58°N. All samples contain background concentrations of 1 to 2 ppm U. Fifteen kilometres south of Cluff Lake the concentration increases to 5 ppm U. Samples of spruce growing in mineralized till, about 300 m south of the worked-out 'D' zone of U mineralization, contain from 73 to 187 ppm U (Fig. 8). Slightly lower values occur 1.5 km southeast of the 'D' zone in an area underlain by Athabasca Group sandstone. Immediately south of the 'D' zone concentrations increase to 946 ppm. One sample from this vicinity was divided into two portions, one of which was thoroughly washed prior to analysis. The unwashed portion had 469 ppm U, and two samples of the washed portion yielded 557 and 559 ppm U. The implication is that the dust on the unwashed portion diluted the U value obtained from the ashed twig, and that airborne dust in this uraniferous vicinity tends to reduce U concentrations in plant ash rather than increase them.

The rocks underlying the Pinehouse/Key Lake road are metasediments of the Mudjatik Domain. The U level of the ashed spruce twigs is higher than those along the Cluff Lake road, generally ranging from 3 to 5 ppm. Close to the uranium mineralization at Key Lake, values reach a maximum of 24 ppm (Fig. 9). Extensive preparation of the ground for mining the uranium has left no trees close to the orebodies. In 1976 samples of the most recent 20 cm of jack pine and black spruce twigs were collected above the Deilmann orebody (Walker, 1979), and yielded from 0.5 to 8.5 ppm U. Concentrations of up to 162 ppm U were encountered over a boulder train a few kilometres to the south.

The biogeochemical response to uranium mineralization is much more subdued in the Key Lake area than in either the Wollaston or Cluff Lake areas (cf. Dunn, 1982a). The reason for this difference is uncertain. It may be due to a lower degree of hydrologic dispersion of U near Key Lake than in the other areas, and the fact that the surface sediments at Key Lake are being constantly remobilized by the wind (i.e. sand dunes have developed since removal of the vegetation).

Around Uranium City samples were collected from easily accessible locations and from a few sites farther afield. Concentrations in excess of 10 ppm U occur in samples over a zone of approximately 8 by 20 km, with the eastern limit still undefined (Fig. 10).

VII. SUMMARY

Biogeochemical studies were conducted for a variety of elements over known mineralization and in areas with no known mineralization. New data are available for the distribution of elements in common plant species of the boreal forest, and the relative sensitivities of these plants and their organs to various types of mineralization. The main observations are summarized as follows:

1. Tungsten: The reported scheelite occurrence of the Radiore C1 zone near Uranium City could not be found visually or geochemically. Either the report was a misidentification of the mineral, or the occurrence has been removed during uranium mining operations. The study showed that conifer and labrador tea twigs tend to concentrate tungsten traces more than other plant parts.

2. Gold: Alder twigs show a tendency to concentrate gold. Enhanced gold values were found over auriferous soils at Cluff Lake, and in the Flin Flon area. The mineralized zone at Waddy Lake was not clearly defined, perhaps due to the extreme immaturity of the soil. Regional surveys defined the Glennie Lake Domain as biogeochemically more auriferous than the La Ronge Domain.

3. Platinum: Plants sampled in the vicinity of the worked-out platiniferous nickel deposit at Rottenstone Lake showed that the twigs of the conifers and labrador tea are more effective at concentrating platinum and palladium than the other plant parts. Slight enrichments of precious metals occur to the north of the old mine where contamination

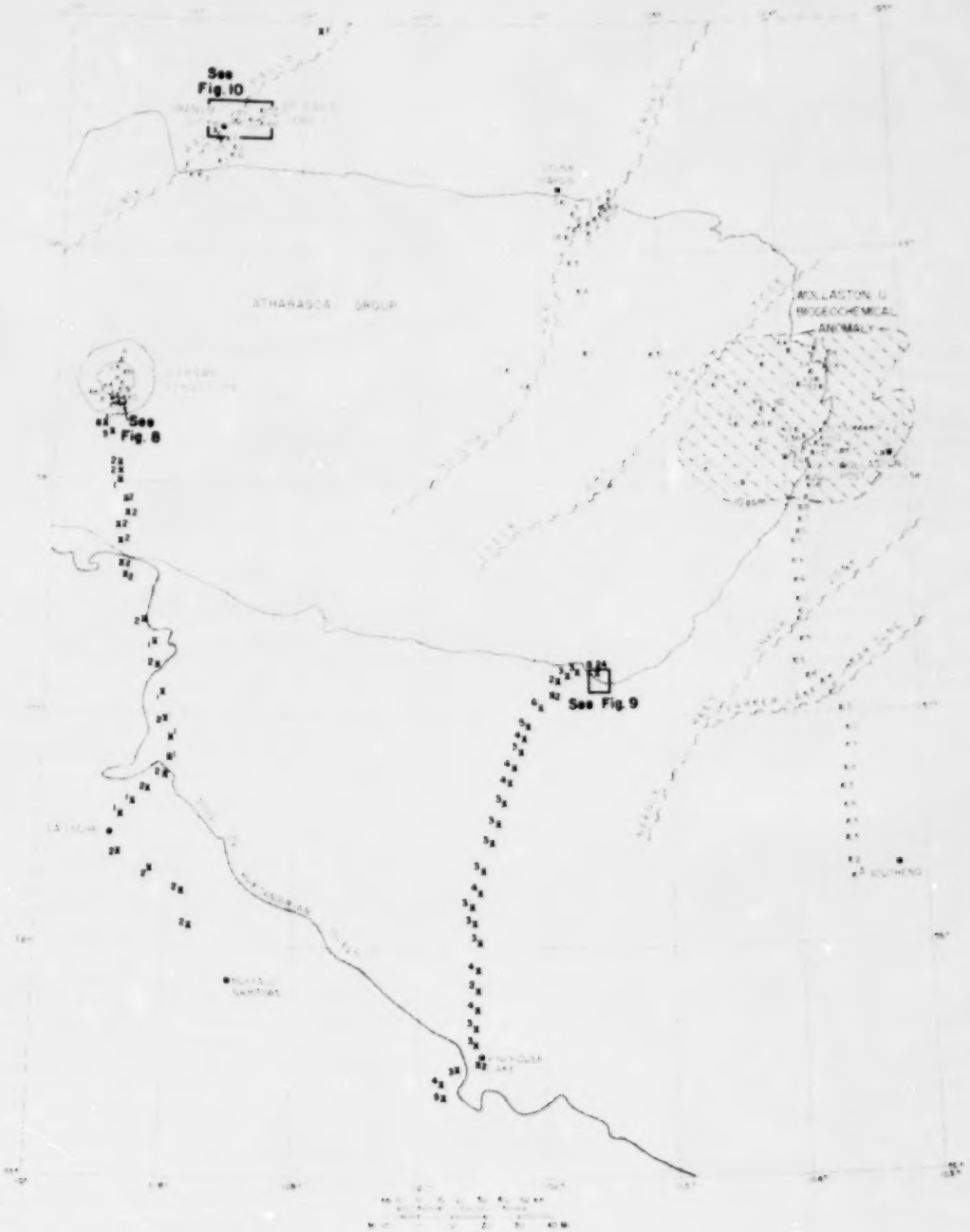

Figure 7 - Distribution of uranium in the ash of black spruce twigs. Grey numbers indicate values published previously; black numbers indicate new data (ppm).

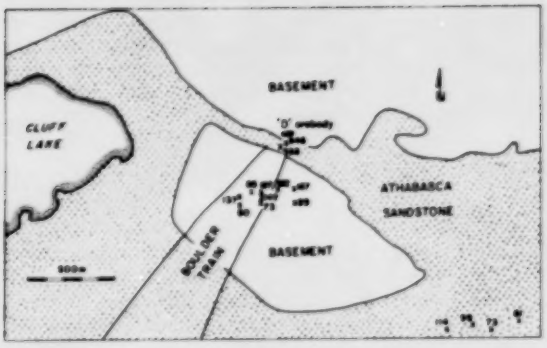

Figure 8 - Uranium in the ash of black spruce twigs, near Cluff Lake. Above the basement to the north of the 'D' zone, concentrations are generally 5 to 8 ppm U.

from mine-workings is unlikely. One spruce trunk yielded an unusually high gold concentration.

4. Rare-earths: The uptake of rare-earths in plants growing close to massive rare-earth rich radioactive allanite varies greatly from one species to the next. Twigs of black spruce contain approximately three times background levels of lanthanum and cerium above some mineralized zones, and higher contents above others. Relatively high concentrations of these elements occur in alder twigs, birch twigs, and trunks of jack pine, black spruce and birch. Samarium tends to follow lanthanum and cerium, but the low levels of lutetium show very little biogeochemical relief.

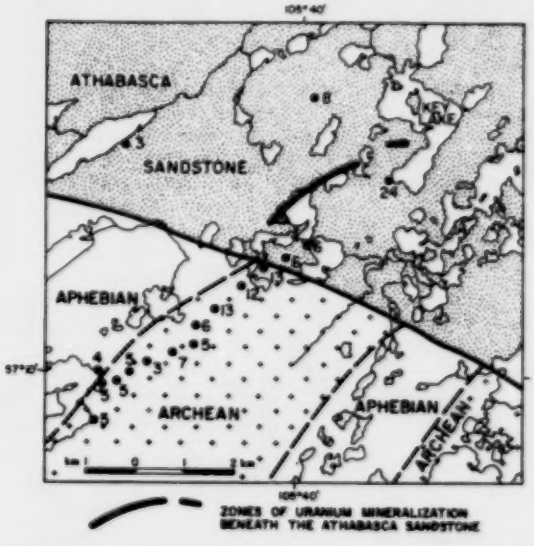

Figure 9 - Uranium in the ash of black spruce twigs, near Key Lake (ppm).

5. Uranium: A continuation of studies on the regional distribution of uranium in ashed black spruce twigs shows that levels are 1 to 2 ppm above Cretaceous sediments along the Cluff Lake road, whereas the levels are 3 to 5 ppm above metasediments of the Mudjatik Domain from Pinehouse to Key Lake. An elongate area around Uranium City, measuring 8 by 20 km and open to the east, contains over 10 ppm U (up to 290 ppm) in all samples analyzed. Studies conducted near zones of mineralization at Cluff Lake and Key Lake showed enhanced values of uranium in the plants, although values at Key Lake were an order of magnitude lower than those at Cluff Lake.

Acknowledgements

I thank all the companies on whose property I have worked for their co-operation in these studies. In particular I thank AMOK Ltd., Key Lake Mining Corporation, and Waddy Lake Resources for their hospitality whilst visiting their operations.

The smooth running and success of a field program is to a large extent dependent upon the assistants with whom one works; hence, I wish to express my gratitude to Pamela Schwann for her efficient assistance throughout the summer; Nikola Jelic, a visiting Yugoslav CIDA fellow, for assistance during the uranium and platinum studies; Guy Buller and Kim Kreis for laboratory assistance. Comments and suggestions of Dr. D.F. Paterson are gratefully acknowledged.

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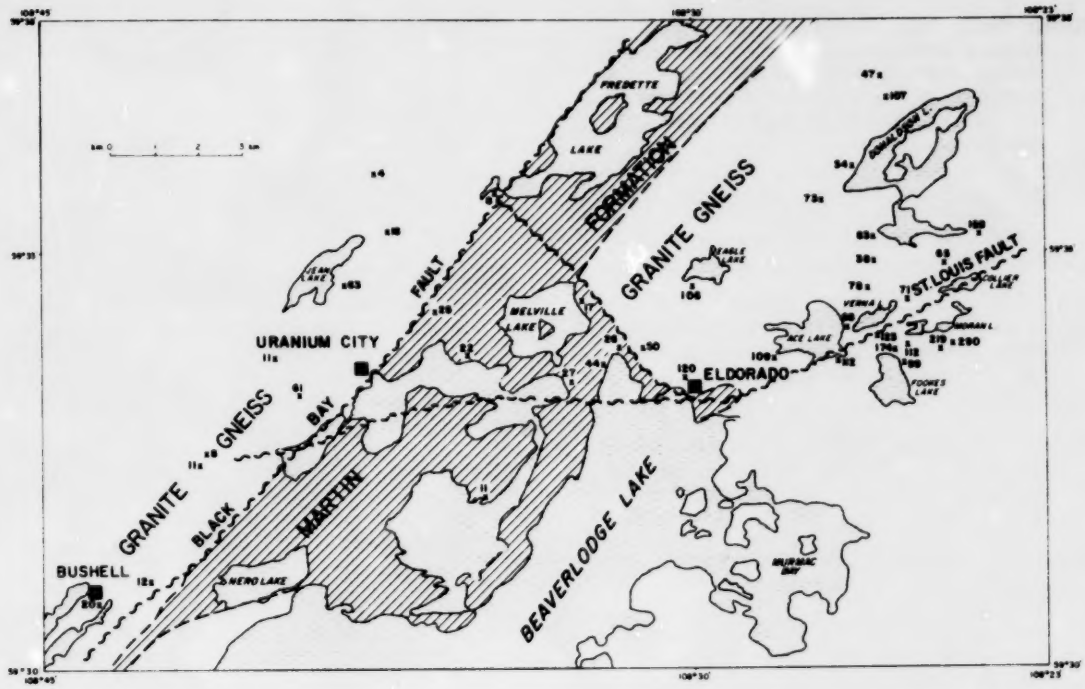

Figure 10 - Uranium in the ash of black spruce twigs, Uranium City.

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Geological Investigation of Mannville (Lower Cretaceous) Deposition in the Tangleflags Area, West-Central Saskatchewan

by Malcolm Wilson

An extensive study of the well logs and cores from the Tangleflags field and surrounding area (Fig. 1) is virtually complete and the synthesis of these data is presently underway. Preliminary evidence points to the dominant deposition mode in the area being nearshore marine through to supertidal shoreline sedimentation. Within this framework there is evidence for channel sequences, scattered both geographically and

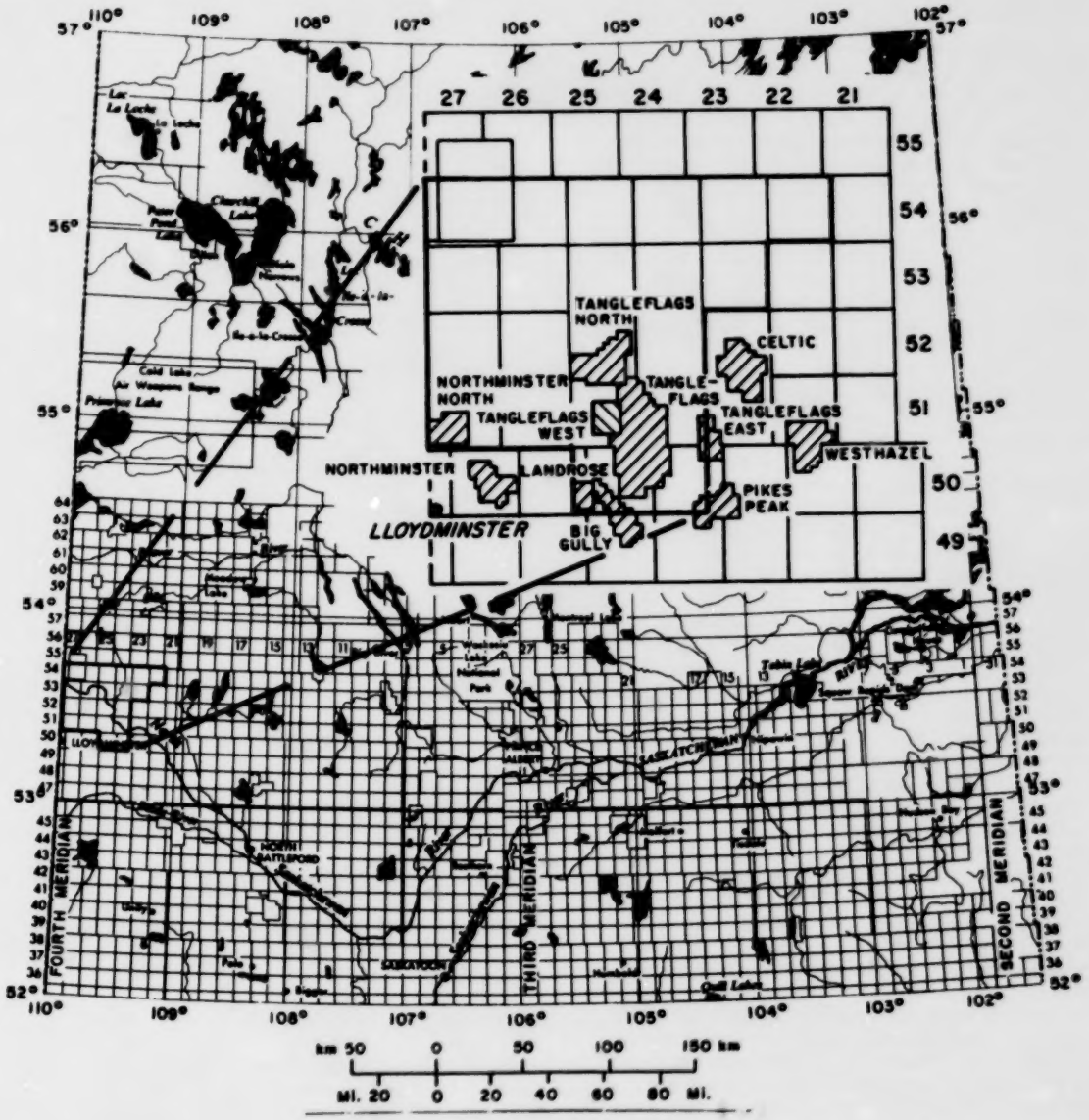

Figure 1 - Area of study and field location map.

chronologically. A series of structural contour maps of units within the Mannville (see Fig. 2 for the Mannville stratigraphy) has been constructed and demonstrates the uniform thickness of the Mannville units. These maps also suggest a slight reduction in structural relief within the Mannville over time. An attempt to eliminate the tectonic component of the structure within the Mannville shows depositional surfaces of very subdued relief and remarkably consistent depositional thicknesses.

General

It is now generally accepted that the Mannville Formation was laid down in a lower Cretaceous sea advancing from the northwest and eventually extending across much of Saskatchewan. Even the non-marine valley fill of the Dina is related to the changing base level resulting from a rising sea level. In the area under study (Fig. 1), very few wells penetrate as far as the Dina or Paleozoic 'basement'; in fact, many do not even penetrate as far as the Cummings. Our view of pre-Mannville topography and the subsequent valley infill, which effectively eliminated much of the pre-existing topography in west-central Saskatchewan, is at present inadequate due to the lack of penetration.

In the Tangleflags area, the marine influence of the Clearwater sea was felt during Cummings time and dominated the depositional environment until at least McLaren time. This evidence can be gleaned from core (see Wilson, 1982) and extended across the area by log correlation. The Mannville from Lloydminster to McLaren was laid down in a series of marine pulses controlled by subsidence caused by the thick clastic wedge building up to the west and the infilling of this shallow seaway by the deposition of clastic sediments. The result is a stacked sequence of transgressive-regressive couplets, each usually culminating in the development of coals/carbonaceous shales overlying sea[illegible]arths. These coals, where they can be determined from log signatures, form excellent lithostratigraphic markers for subdivision of the Mannville. One particular coal, at the top of the Sparky, is ubiquitous. It shows up clearly on the gamma/sonic or gamma/neutron density logs as the only consistently 'clean' coal; the gamma kick indicates low natural radiation which, in lithologic terms, suggests low shale influx. The Sparky coal has been used in this study as a datum in an attempt to eliminate the effects of any tectonic (including salt-tectonic) influences on the

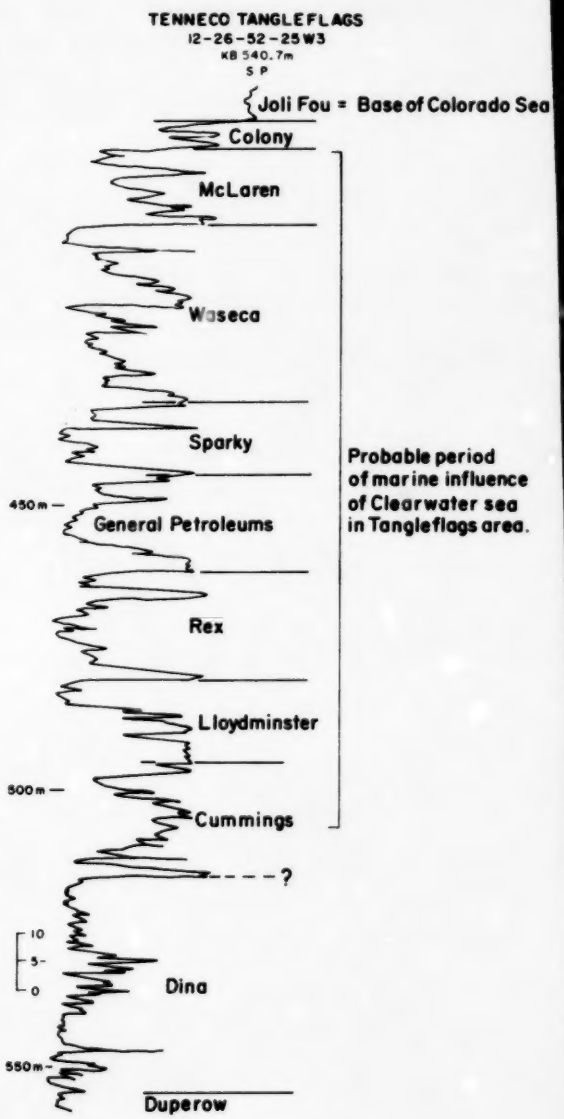

Figure 2 - Log 12-26-52-25W3, illustrating stratigraphic subdivision of the Mannville (modified from Wilson, 1982).

Mannville. Structure maps using the Sparky coal as a datum produce some interesting results when compared to the structure maps using a sea-level datum.

Preliminary Findings

In the Tangleflags area (Fig. 1), there exist over 1000 wells with logs and almost 80 cores. Unfortunately, the geographic distribution of these wells is very uneven,

resulting in rather variable levels of confidence for the contours in the map area. Within the field areas, these contours can be considered quite reliable when they are based on well-defined lithostratigraphic breaks that appear as clear signatures on the logs. It has become evident during the course of this investigation that, within the Tangleflags area, the distinction between two units, the Sparky and General Petroleums (GP), is an example of a "spiral correlation" (see Gross, 1980). In effect, the breakdown between these two units depends on the starting point of the line of correlation and so, for this reason, it may prove convenient to combine them under one name.

The two maps reproduced in this summary (Figs. 3 and 4) show the structure on the top of the Lloydminster unit using a sea-level datum at a contour interval of 10 m (Fig. 3) and the structure on the same unit using the Sparky top (coal) as a datum (Fig. 4) with a contour interval of 4 m to enhance the detail.

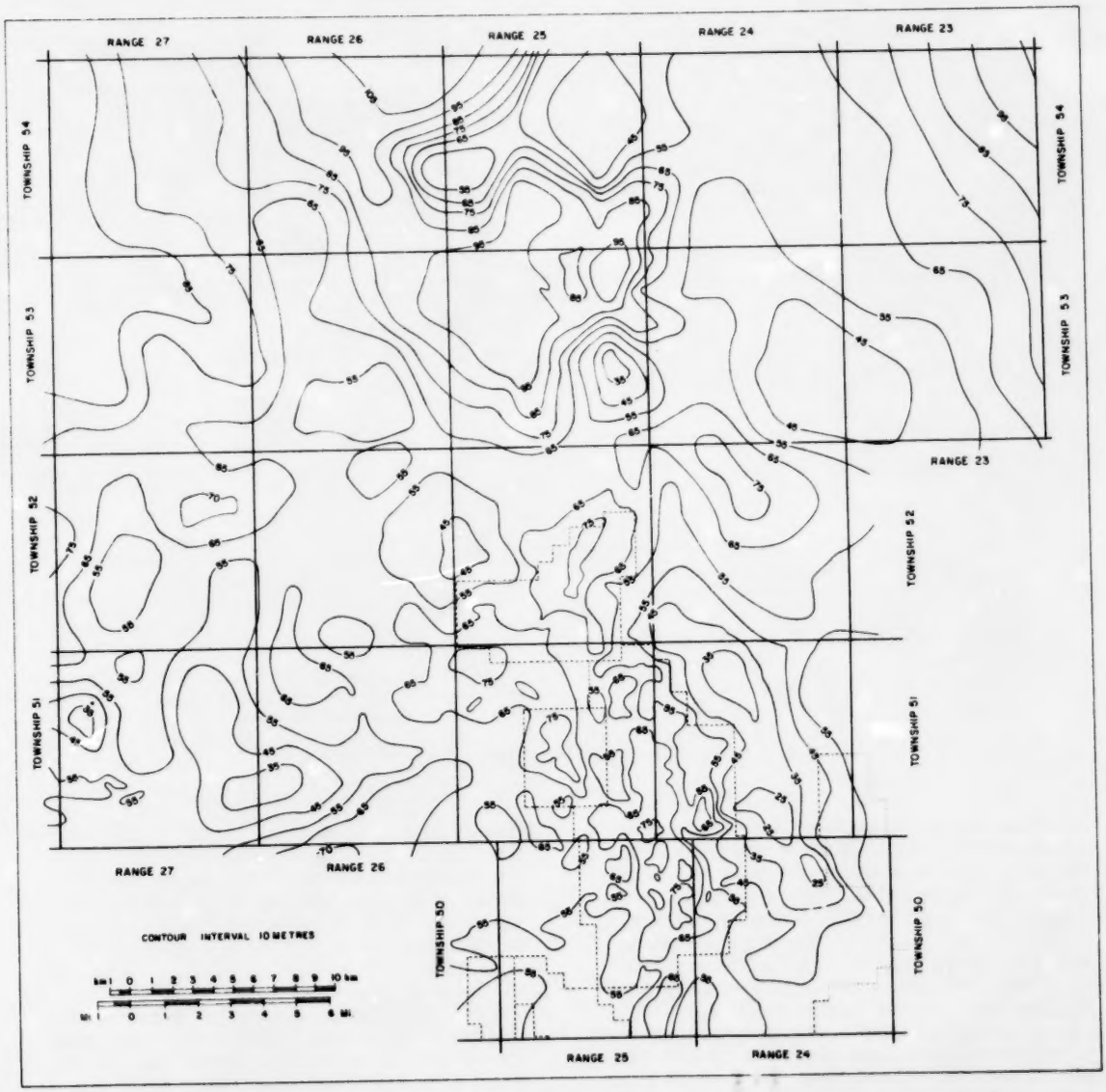

Figure 3 - Structure contour map of the Lloydminster top using sea-level as datum. All heights above sea level.

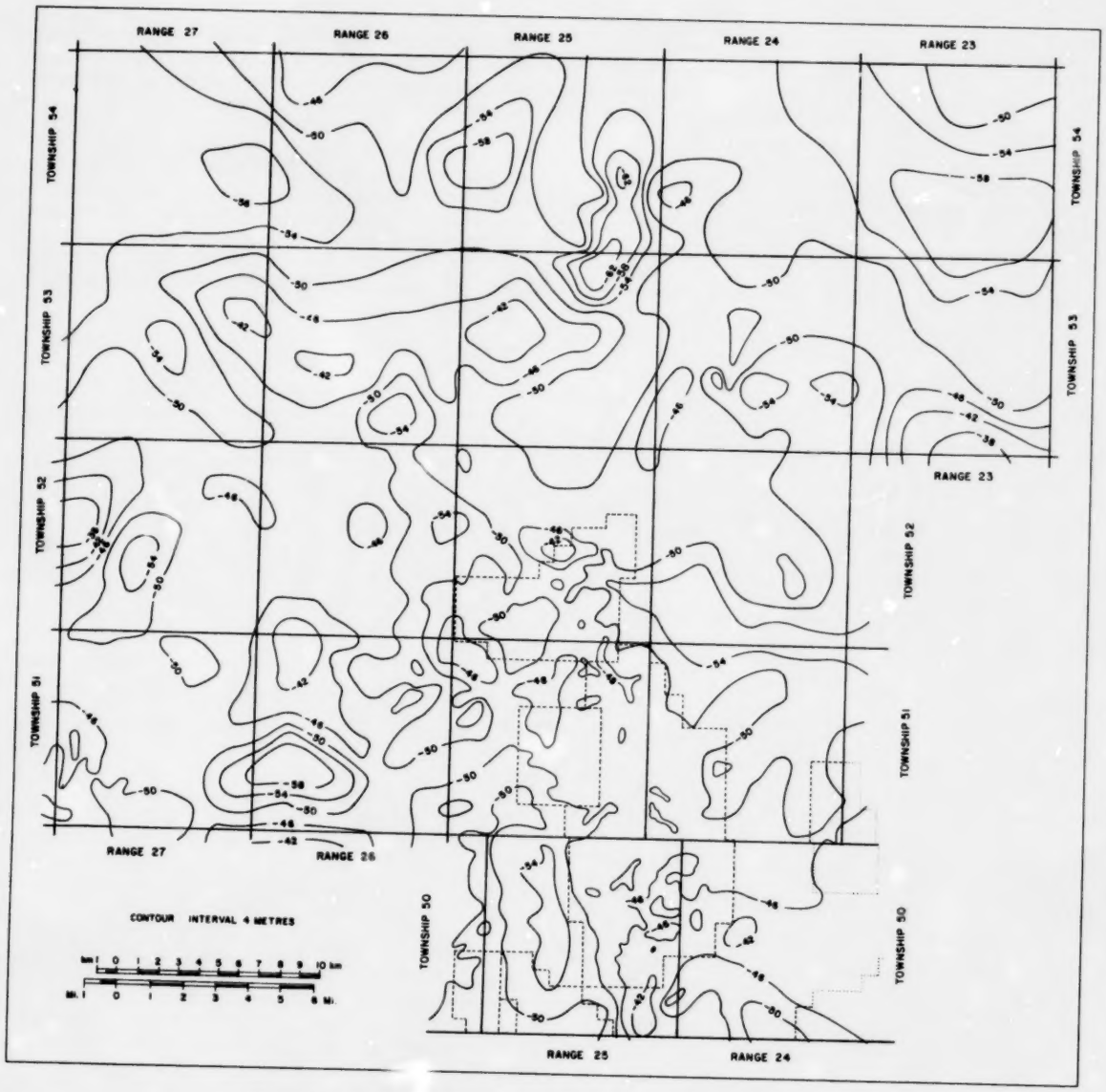

Figure 4 - Depths to Lloydminster top using the Sparky top as a datum.

Other maps (not reproduced here) have been constructed using obvious log markers. All the structure maps using a sea-level datum (tops of Lloydminster, Rex, Sparky and Colony) show essentially the same pattern of highs and lows (some of the more anomalous features peripheral to the fields may have resulted from imprecise logging depths or survey heights, and consequently are given little consideration). Not only are all significant structural features in the same place, but the relief they indicate is also remarkably consistent; for example, the change in height moving east from Tangleflags into the flanking low is 50 m at the top of the Lloydminster, Rex, and Sparky and only drops to 40 m at the top of the Mannville (Colony). Fig. 4 indicates basically two things: the low relief of the area when structural effects are eliminated (a relief in the area mentioned above of only 6 to 8 m) and the relatively uniform thickness of the Lloydminster to Sparky interval. The same points hold true for the top of the Mannville, the Waseca to Colony interval.

In addition, one can also determine that the structural highs, the proven or potential oil traps, coincide with a thinning of the sediments. This fact indicates that the highs are related to tectonic activity rather than differential compaction within the sedimentary pile. The uniformity of the maps also suggests that this tectonic activity was occurring during, as well as after, Mannville deposition. The decreased relief, with and without structural influence, in evidence at the top of the Mannville suggests again that part of this activity occurred during Mannville time and that some levelling of the terrain occurred in non-marine, late Mannville time, in other words, following the final withdrawal of the Clearwater sea. Core and log evidence point to the Colony being non-marine over much of the area. At this time, therefore, we are seeing the tendency towards elimination of any relief by largely continental erosional and depositional processes. Following this event was the transgression of the Colorado sea over the entire area.

Paleoenvironmental Implications

The temporal continuity of the high that exists over Tangleflags and Tangleflags North (Figs. 1 and 3) suggests that we may be looking at a peninsula which was flooded during transgressive phases of the Clearwater sea but became emergent rather early in the regressive phases. On the other hand, the Celtic field (Fig. 1), which lies to the east of Tangleflags, displays sedimentary features suggestive of a more offshore position, with the development of sandbars (Lorsong, 1980). Such a concept ties in well with this speculative picture of Tangleflags. Wilson (1982) found evidence for a Lloydminster channel in Tangleflags North. From the information available, the trend of this channel feature coincides with an elongate high (75+ m above sea level in Fig. 3) which trends northeast out of Tangleflags North. There are still insufficient drilling data to delineate the northeastern limit of this channel, but the maps suggest that evidence from farther northeast and to the east of the channel should prove useful in outlining this geographic feature.

Further Studies

Interpretations made from this study will be tested by further investigations and by comparison with other studies and additional evidence gleaned from a continuation of this one. It must be stressed that interpretations and conclusions drawn here are speculative at the present time.

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Appraisal of Long-Range Hydrocarbon Supply from Conventional and Low-Permeability Reservoirs in the Marine Cretaceous Sandstones of Saskatchewan: Initial Established Reserves Related to Reservoir Facies

by Frank Simpson[1]

Marine sandstone bodies of the Colorado and Montana Groups (middle Albian to Campanian) have yielded commercially important production of light oil and non-associated natural gas from depths in the range 335 to 732 m in western Saskatchewan since 1945 (Saskatchewan Energy and Mines, 1983a, 1983b). The producing strata include the largely conventional reservoirs of the Viking Formation in west-central Saskatchewan and the low-permeability reservoirs of the Milk River Formation and the Medicine Hat Sandstone in the southwest. Sandstones and siltstones occurring throughout the Colorado and Montana Groups are prospective for hydrocarbons over a wide area of southern Saskatchewan (Simpson, 1982a).

During the summer of 1983, a detailed study of all Saskatchewan oil and gas pools producing from the Colorado and Montana Groups was carried out as the first stage in a two-part investigation of long-range hydrocarbon supply from the succession. In the present account, the initial established reserves of crude oil and natural gas estimated for the Colorado and Montana Groups by Saskatchewan Energy and Mines (1983a) are related to the facies of the reservoir strata. These relationships and the search rationales outlined by Simpson (1982a) are to provide the basis for an estimate of the volume of undiscovered hydrocarbons in the succession, to be completed in the summer of 1984.

Initial Established Hydrocarbon Reserves of the Colorado and Montana Groups

The terminology for hydrocarbon reserves and resources adopted in the present study (Fig. 1) is to a large extent that employed by the Alberta Energy Resources Conservation Board (1983) for all energy resources. Some minor modifications pertaining to undiscovered hydrocarbon accumulations have been taken from the most recent report by the Potential Gas Committee (1983).

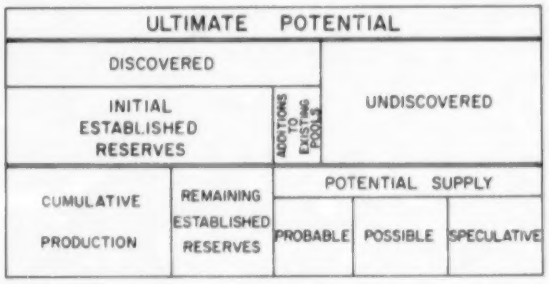

Figure 1 - Categories of hydrocarbon reserves and resources (modified after Alberta ERCB, 1983; Potential Gas Committee, 1983).

The largely conventional reservoirs of the Viking Formation in west-central Saskatchewan have accounted for virtually all of the initial established reserves of crude oil in the Colorado and Montana Groups, estimated at 15.140×10^6 m^3, or about 4 percent of the provincial total. On the other hand, initial established reserves of natural gas in the succession have included accumulations in extensive low-permeability reservoirs of the Milk River Formation and the Medicine Hat Sandstone of southwestern Saskatchewan, amounting to $50,356.5 \times 10^6$ m^3, or about 68 percent of the provincial total. On December 31, 1982 the Colorado-Montana succession contained 5.757×10^6 m^3 remaining established reserves of crude oil and $29,214.1 \times 10^6$ m^3 remaining established reserves of natural gas, or 6 and 68 percent of the respective provincial totals.

Conventional Reservoirs

The Viking Formation of west-central Saskatchewan consists of shaly sandstones and conglomerates in dominantly coarsening-upward sequences, reflecting sedimentation on the shallow western shelf of an epeiric sea (Simpson, 1982b). The unit decreases markedly in thickness and concomitant grain size in a northeasterly (basinward) direction. The deposits of nearshore proximal-shelf and distal-shelf settings were recognized on the basis of gross lithology

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Project received financial support from Saskatchewan Energy and Mines.

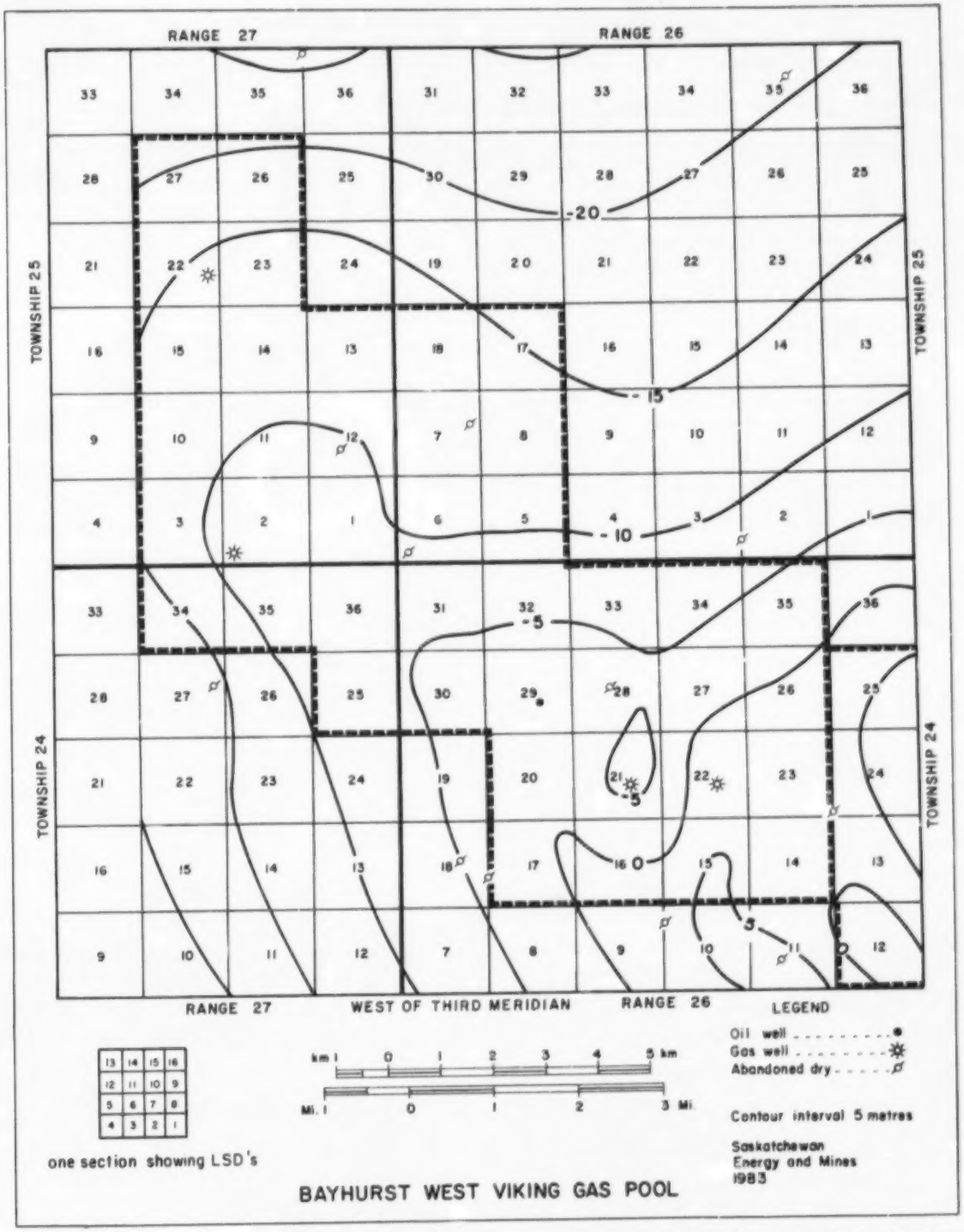

Figure 2 - a) Structural contours on the Viking Sand of the Bayhurst pool, west-central Saskatchewan; b) stratigraphic cross-section across the Bayhurst pool.

and associations of sedimentary structures, and distinctive reservoir characteristics were shown to be associated with each of the generalized depositional environments (Simpson, 1982b, Table 1, p. 82).

The nearshore deposits are characterized by widespread well-washed sandstones in planar foresets. Primary reservoir heterogeneities (shale breaks) occur with increased frequency downwards and secondary heterogeneities (cementation barriers) are commonly found at the top of the unit. Porosities are commonly in the range 25 to 35 percent and maximum horizontal permeabilities are from a few hundred millidarcies to nearly 2000 millidarcies. This facies is represented in the Viking reservoir strata of the Bayhurst pool (Fig. 2). The Bayhurst and Bayhurst West pools have initial established reserves of non-associated natural gas amounting to 2,168.5 x 10^6 m^3. These pools occur in structures associated with drape folds in the marine Cretaceous succession, in part coincident with the northern erosional limit of Jurassic strata at the sub-Cretaceous unconformity.

The proximal-shelf deposits are largely made up of bedded shaly sandstones, succeeded upwards by bioturbated shaly sandstones, with subordinate conglomerates being common near the top of the unit. Primary reservoir heterogeneities are abundant in the lower part of the sequence and secondary heterogeneities are found near the top. The proximal-shelf strata exhibit porosities of 20 to 30 percent in the bioturbated deposits, whereas values of 15 to 25 percent are typical for the bedded shaly sandstones. Permeabilities of up to several hundred millidarcies characterize these deposits.

The Viking strata of the Brock pool (Fig. 3) are typical for the proximal-shelf setting. The proximal-shelf deposits account for initial established reserves of non-associated natural gas amounting to 20,402.5 x 10^6 m^3. However, it is noteworthy that 63.6 percent of these reserves are contained in the Coleville-Smiley, Dodsland North and Hoosier pools, located along the Dodsland-Hoosier production trend, which is characterized by drape folds in the Colorado succession, coincident with the northern, erosional edge of Mississippian strata at the sub-Cretaceous unconformity. The proximal-shelf facies contains all of the Viking high-gravity crude oil discovered in west-central Saskatchewan, and initial established reserves of associated natural gas equal to 29.5 x 10^6 m^3.

The distal-shelf strata of the Viking Formation are largely made up of bedded and bioturbated shaly sandstones with porosities of 15 to 25 percent and permeabilities of up to several tens of millidarcies. The only hydrocarbon production from this facies was at Unity (Fig. 4), where initial established

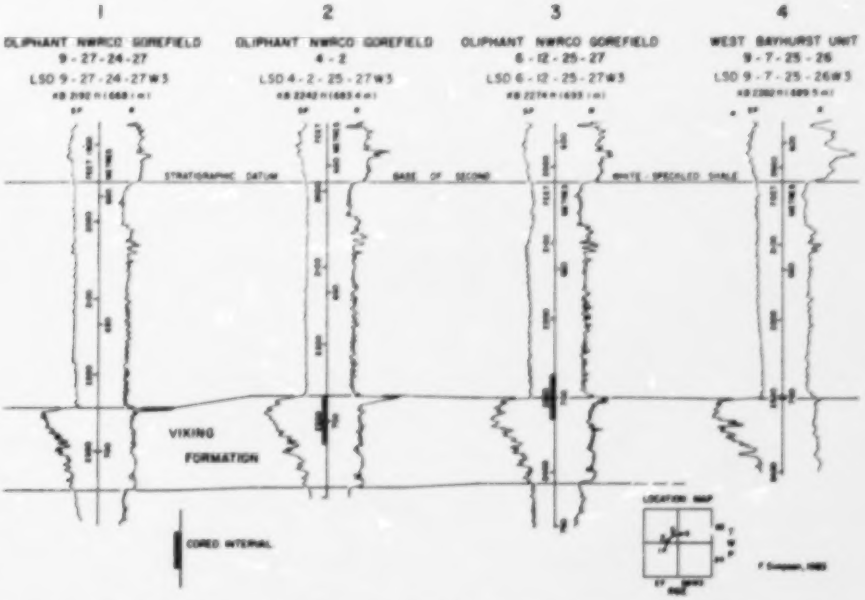

Figure 2 - b) Stratigraphic cross-section across the Bayhurst pool, west-central Saskatchewan.

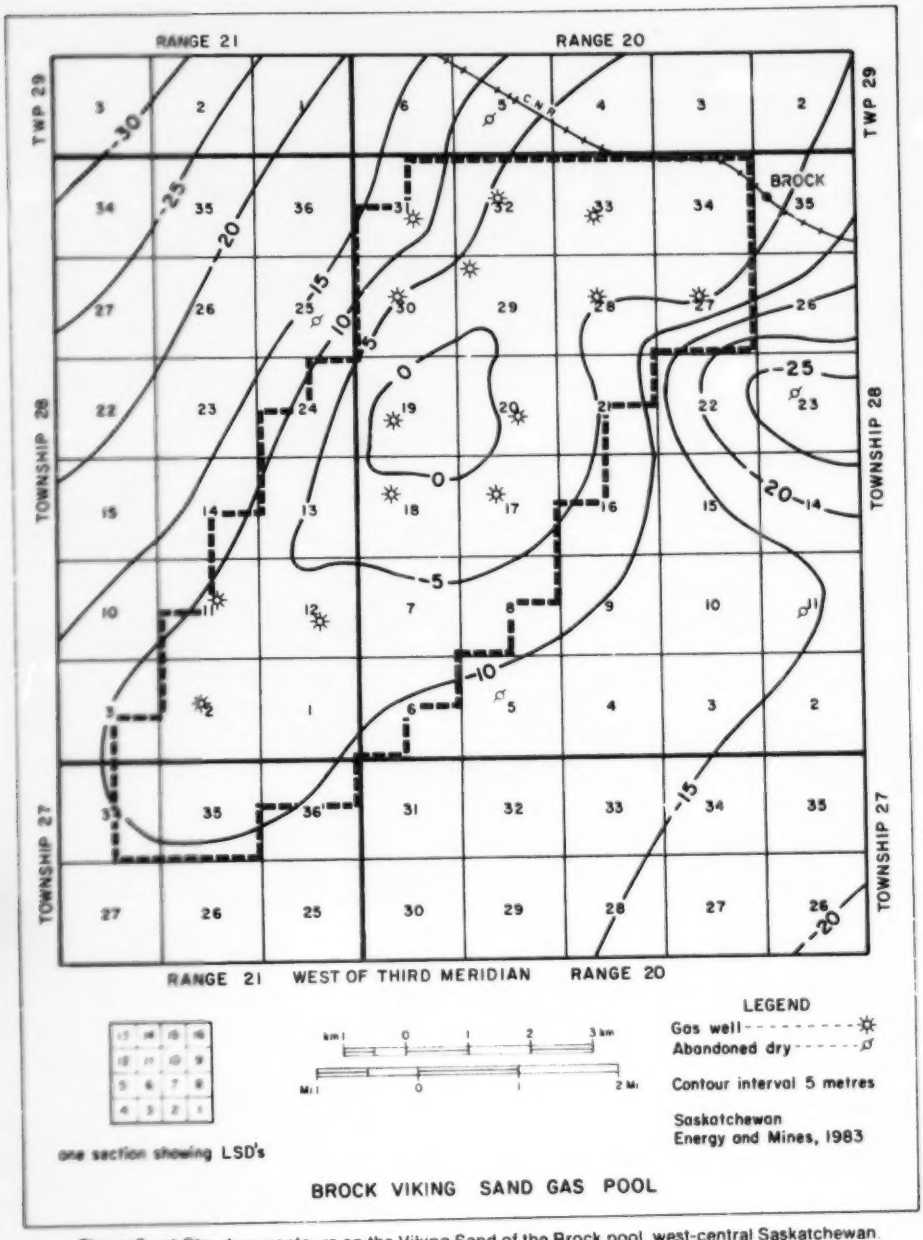

Figure 3 - a) Structure contours on the Viking Sand of the Brock pool, west-central Saskatchewan.

reserves were 14.4 x 10^6 m^3. The Unity pool is associated with structure in the Colorado sequence, coincident with the northern erosional edge of the Upper Member of the Birdbear Formation (Devonian) at the sub-Cretaceous unconformity.

Low-Permeability Reservoirs

The Milk River Formation of southwestern Saskatchewan consists of 120 m of bioturbated sandstones and siltstones, which incorporate scarce sandstone lenses and layers of concretionary siderite. Porosities are

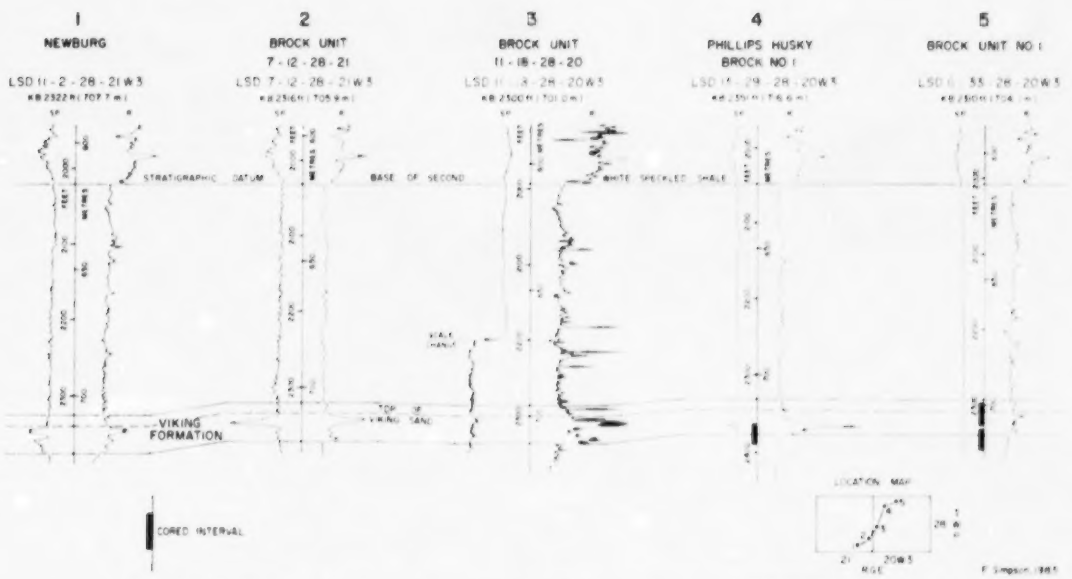

Figure 3 - b) Stratigraphic cross-section across the Brock pool, west-central Saskatchewan.

generally less than 20 percent and permeabilities are commonly less than one millidarcy. The unit was deposited in a shallow marine-shelf setting. The Milk River Formation of the Hatton and Liebenthal districts contained initial established gas reserves of 15,264.1 x 10^6 m^3 or 30.3 percent of the initial established reserves in the marine Cretaceous sandstones of Saskatchewan.

The Medicine Hat Sandstone comprises about 13.7 m of muddy, very fine- and fine-grained sandstones and intercalated sandstones and shales. The unit is made up of bedded shaly sandstones, commonly succeeded by bioturbated shaly sandstones in dominantly coarsening-upward sequences. Primary reservoir heterogeneities tend to decrease in frequency and thickness upwards. Secondary heterogeneities are calcareous concretionary layers, occurring near the top of the unit. Porosities vary from 5 to 30 percent to give an average of 16 percent, and permeabilities range from 0.1 to more than 250 md. The initial established reserves of natural gas in the Medicine Hat Sandstone were 10,262.6 x 10^6 m^3 or 20.4 percent of the total for the Colorado and Montana Groups of Saskatchewan.

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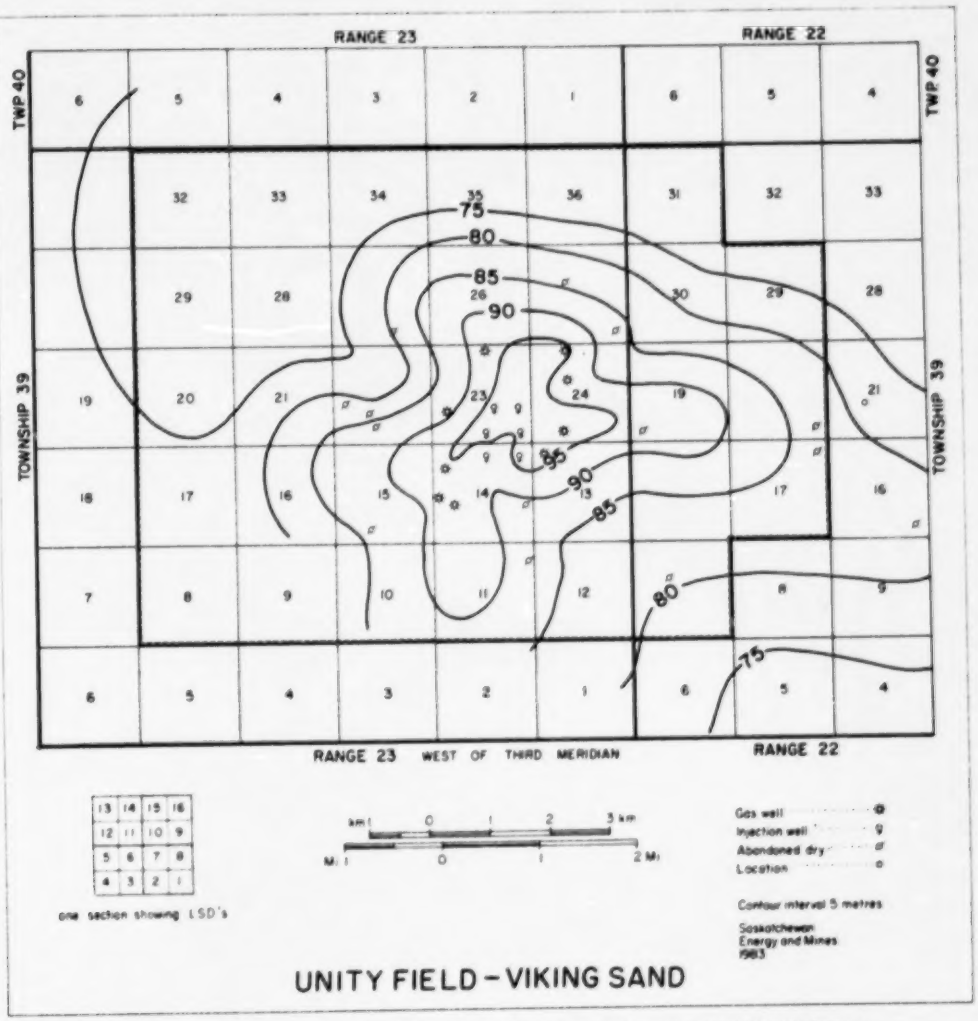

Figure 4 - a) Structure contours on the Viking Sand of the Unity pool, west-central Saskatchewan.

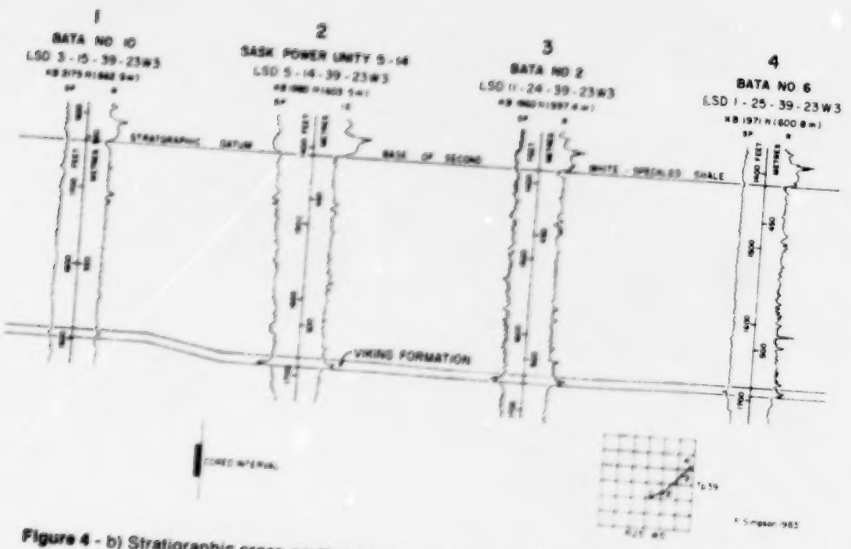

Figure 4 - b) Stratigraphic cross-section across the Unity pool, west-central Saskatchewan.

INDUSTRIAL MINERALS INVESTIGATIONS

Fuel Peat Demonstration Project

by P. Guliov

Field work on this project commenced during 1981 and was forced to a premature conclusion due to budgetary restraints during 1982-83. Despite this fact and the mild winter in the Buffalo Narrows region during the trial period, a small amount of local fuel peat was tested for domestic heating. The greatest proportion of the testing, however, was carried out with imported peat fuel of a similar quality. Due to a late production cycle, rainy weather and an early frost, the local sod fuel peat did not dry adequately on the bog. Consequently several tonnes of the sods were gathered for indoor drying. About six months were required to reduce the moisture level from about 75 percent to about 40 percent.

Fuel Peat Trials

The local and imported peat fuel was of the extruded sod type with a diameter of about 5 cm and lengths ranging up to about 15 cm. The characteristics of the Buffalo Narrows fuel peat are compared with those of the imported Finnish fuel peat in Table 1.

Table 1. Comparison of Buffalo Narrows and Finnish Fuel Peat (Weight Percent Dry Basis)

	Buffalo Narrows Demonstration Bog	Finnish Fuel Peat
Ash	3.8	6.5
Volatile Matter	70.1	67.8
Fixed Carbon	26.1	25.7
Sulphur	0.13	0.41
Calorific Value	5397 kcal/kg (9724 BTU/lb.)	5328 kcal/kg (9600 BTU/lb.)

The fuel peat was used to heat three homes and a public building in Buffalo Narrows during the winter of 1982-83. Two imported multi-solid fuel boilers (18 and 22 kW) and two Canadian-made combination oil-wood furnaces were utilized for the trial period. Two additional homes using only oil in Canadian-made furnaces were monitored for comparative purposes. The five homes involved in the trial period were of similar size and design. All were tested for air infiltration and rate of thermal loss to provide a rational basis for comparing fuel consumption.

Although interpretations of technical data had not been completed at the time of writing, some general conclusions and observations are possible.

Conclusions and Observations

1. Peat Fuel Production:
   (a) Production of fuel peat sods is technically feasible in the Buffalo Narrows area near the southern limit of permafrost.
   (b) The long-term average climate in the area is suitable for a fuel peat operation.

2. Peat Fuel Quality:
   (a) The relatively high fibre content in the Buffalo Narrows peat provides good binding properties which tend to produce a durable sod and reduce the development of fines in handling.
   (b) The local peat functioned as well as or better than the Finnish fuel peat in domestic heating trials.
   (c) The imported peat fuel produced a brown ash, whereas the local peat produced a white or grey ash.

3. Peat Fuel Utilization:
   (a) Some problems were encountered with peat dust and ash during loading and ash cleanout.
   (b) Hydronic units are necessarily more complex than conventional units and this is significant in terms of capital and installation costs.
   (c) The complexity of hydronic peat-burning furnaces demands that the users be carefully trained in their use and potential hazards.
   (d) Currently available Canadian-made oil-wood units require far less skill and training in their operation but require more frequent attention.
   (e) The effort required by peat fuel utilization, whether in a hydronic or normal hot air unit, is considerably greater than that for an automatic gas or oil-fired unit. This, however, may be partially overcome by automatic stoking devices.
   (f) Creosote build-up in the chimney flues of the test homes and public building was negligible.

(g) A 20 to 30 percent fuel wastage was attributed to the discarding of most of the fines by the users and to the passage of fines through the furnace grates.

(h) Hydronic furnaces with ample hot water storage provided far better heat control than the normal hot air units which provided more intense heat for shorter periods.

4. Economics of Fuel Peat Heating:

(a) Although hydronic units functioned well, the high capital and installation costs make them unattractive for domestic heating.

(b) In a community such as Buffalo Narrows and nearby areas with about 400 domestic units, a high proportion of the units would have to convert to peat heating in order to justify the necessary capital investment and operating costs for a peat fuel operation. A high proportion of conversion would require several years, during which time residents could become familiar with the use of peat and its advantages and disadvantages.

(c) The economics of peat-based district heating appear to be more attractive than individual domestic peat heating. Individual capital costs in this case would be far less than required for individual hydronic units.

(d) The economics of domestic peat will, in part, depend on the level of demand for fuel in relation to the productive capacity of a mining operation. An improvement in the economics could be realized if domestic use were coupled to a large local primary demand such as a power generating facility, a coking plant or a large industrial user.

Recommendations

1. Technical and economic feasibility of peat-based district heating concepts should be investigated particularly in areas which have a large demand potential and could justify development costs.

2. Solid peat fuel functions well as a domestic stove fuel. Examination of this potential market may assist in improving the economics of a peat mining operation geared to district heating.

3. Prospects for utilizing peat fuel for large-scale industrial heating in northern areas should be investigated.

4. The potential for the production of other fuel and non-fuel products from peat should be investigated.

Petrology of the Middle Devonian Prairie Evaporite Potash Ore in Saskatchewan

by L. M. Fuzesy

Study of the Saskatchewan potash ore was continued during 1983. The objective of this work is to understand geological problems which affect or have the potential of affecting the economics of potash mining and safety of the mines. Particular attention is given to the problems of the origin and the lateral and vertical extent of carnallite, the presence of which is undesirable in the potash mines but may be economically attractive for magnesium production. Material upon which observations and conclusions are made includes about 250 samples from drill cores and potash mines, 85 thin sections and chemical analyses of sylvite, carnallite and halite separated from 63 samples. Geological data and cores from over 500 boreholes were examined.

Potash ore in Saskatchewan occurs in the southern part of the province and is of Middle Devonian age. Six potash shaft mines are situated in the Saskatoon mining district, three shaft mines are located in the Esterhazy-Rocanville area and one solution mine is present at Belle Plaine. The potash beds occur within the upper 70 m of the Prairie Formation. These beds comprise mainly a mixture of halite and sylvite and/or carnallite. The Prairie Evaporite consists primarily of halite with some anhydrite, carbonate and shale interbeds in addition to potash ore. The thickness of the formation varies between 140 and 200 m. It lies about 1000 m below surface in the Saskatoon and Esterhazy-Rocanville areas and around 1600 m at Belle Plaine. The Prairie Evaporite conformably overlies the predominantly carbonate layers of the Winnipegosis Formation, and is unconformably overlain by the Second Red Beds of the Dawson Bay Formation. Partial or complete removal of salt by solution from local or larger areas is a common phenomenon throughout Saskatchewan. The regional gradient is to the south and southwest at 3 to 9 m/km. Fig. 1 is a structure contour map on the Prairie Formation in the Bredenbury-Esterhazy-Rocanville area.

Sediments of the Prairie Evaporite were deposited in the Elk Point Basin from highly restricted, hypersaline waters. Salinity of this large inland sea attained its highest level in the southeastern portion of the basin, resulting in potassium salt precipitation in the upper part of the Prairie Formation. The four potash-bearing members of the Prairie Formation are called, in ascending order, Esterhazy, White Bear, Belle Plaine, and Patience Lake (Fig. 2). The successively higher members extend farther towards the northwest. The Esterhazy and Rocanville mines produce from the Esterhazy Member. The six mines in the Saskatoon area are producing from the Patience Lake Member, and the Belle Plaine Member is solution mined at Belle Plaine along with the other members.

Description

The halite (NaCl) is mainly colourless or white to brown, with crystals ranging in size from about 5 to 25 mm in the Esterhazy Member and from 5 to 18 mm within the overlying strata. In thin section the halite is isotropic, commonly with cubic cleavage. The sylvite (KCl), the main ore mineral, is very similar in appearance to halite. The carnallite ($KCl.MgCl_2.6H_2O$) ranges from light brown to dusky red. Its crystals are orthorhombic and range in size from 2 to 10 mm in the Esterhazy Member and 50 to 80 mm in the higher potash-bearing members. Carnallite veins are common, and in the Esterhazy and Rocanville mines reddish-brown carnallite crystals are locally concentrated into vertical stripes and bands. Relict sylvité commonly occurs in carnallite crystals and carnallite replacement can be observed in many cases in the outer part of sylvite crystals. Carnallite has no cleavage, but ghost outlines of cubic cleavage are commonly observed in the crystals.

Carnallite-rich orebodies occur mainly in the area between the South Saskatchewan River and the Assiniboine River (Figs. 3 and 4). The maximum lateral extent of these zones is about 28 km (south of Quill Lakes). Wherever carnallite was encountered in the boreholes within these areas, the occurrence of carnallite is more widespread in the lower members than in the higher members (Fig. 5). For example, it may be present in the lower two members and in the lower part of the third member, or it may occur only in the lower part of the lowest member. In the Esterhazy Member the carnallite normally occurs together with halite and sylvite, and generally does not comprise more than 25

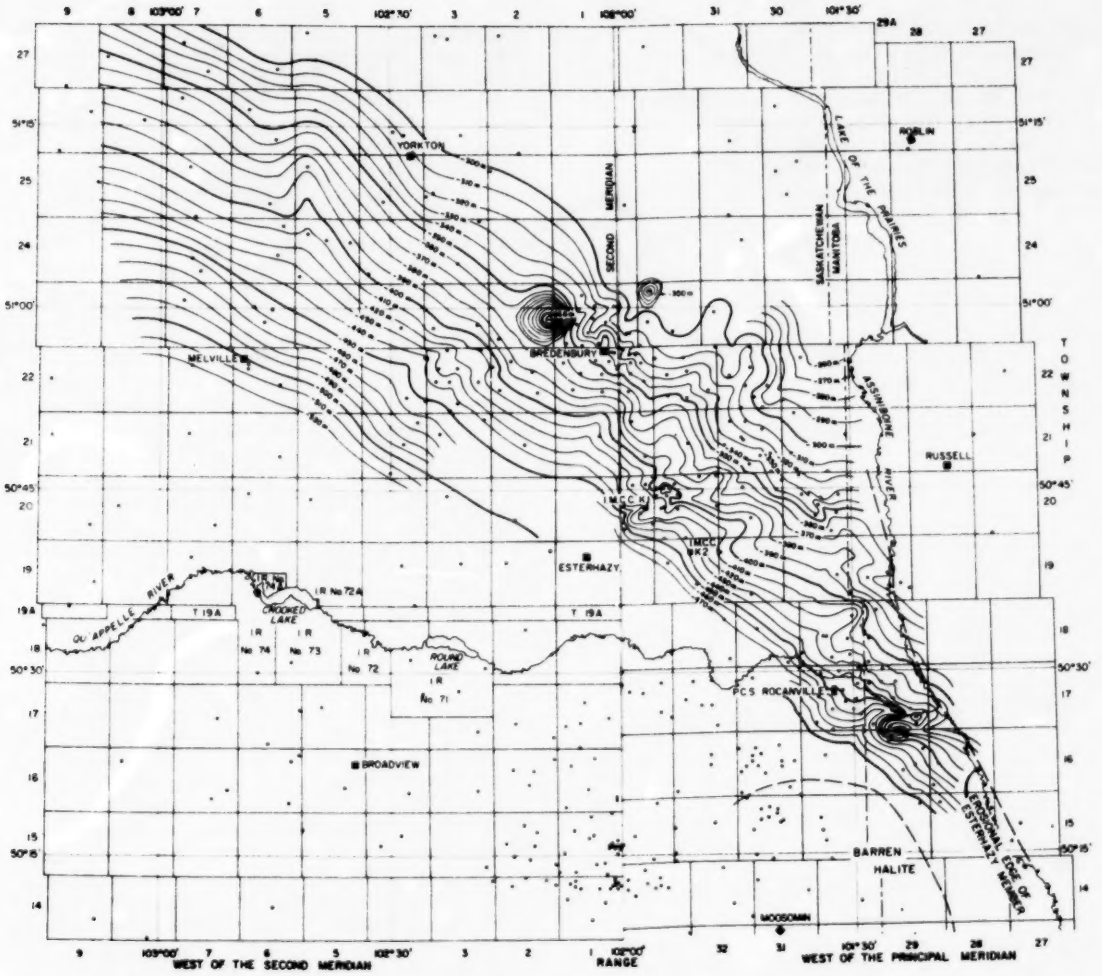

Figure 1 - Structure contour map on the Prairie Formation.

percent of the total rock mass. Within the potash members above the Esterhazy Member, carnallite is associated with halite only (sylvite is absent) and the carnallite content of the layers is much higher than in the Esterhazy Member, up to 90 percent in many boreholes. The thickness of a carnallite-rich zone is 30 to 150 percent greater than the same stratigraphic interval with no carnallite content. Vertical to near-vertical fractures occur commonly within carnallite-rich zones and are normally filled with clay and/or carnallite.

The potash mines in the Saskatoon area are relatively free of carnallite, but many carnallite-rich orebodies have been encountered in the Esterhazy-Rocanville mines. The potassium content of the carnallite is 14 percent, as opposed to sylvite, the desired mineral, which contains 52 percent potassium.

The amount of bromine in halite, sylvite and carnallite is significant in the interpretation of the origin of these minerals. During the evaporation of brines, the bromine does not form independent minerals but rather occurs as a solid solution substitution for chlorine in chloride minerals. Halite is the first mineral to precipitate, followed by sylvite and finally carnallite. The bromine content of a chloride mineral is dependent on the amount of bromine in the crystallizing solution and also on its own distribution coefficient (intake ratio). The distribution coefficients for halite, sylvite and carnallite are less than 1; consequently, the bromine content of the residual seawater

progressively increases after the precipitation of the first halite crystal.

According to Valyashko (1956, p. 578) and other workers, the bromine content of halite should be 270 ppm at the beginning of sylvite precipitation. However, 60 halite samples analyzed from the Esterhazy Member were found to contain only around 120 ppm bromine, suggesting that recrystallization has taken place. Bromine values in sylvite and carnallite from the Esterhazy Member are around 1300 ppm. This figure is also low in comparison with bromine in these potash minerals precipitated from present-day seawater. However, it is significant that the average value of bromine in sylvite and carnallite is the same, suggesting that one mineral replaced the other and incorporated its bromine content. Only a few samples from each of the higher members, above the Esterhazy Member, have been analyzed, but the results indicate a gradual upward decrease in bromine values. The average bromine contents in the halite from the Esterhazy, White Bear, Belle Plaine and the Patience Lake Members are 110, 99, 81 and 61 ppm respectively, while the sylvite from the same members averages 1380, 1180, 740 and 410 ppm bromine respectively. More analyses are required for the confirmation of this trend. The upward decrease in bromine content, if confirmed, would provide valuable additional information regarding the depositional history of the Prairie Evaporite in Saskatchewan.

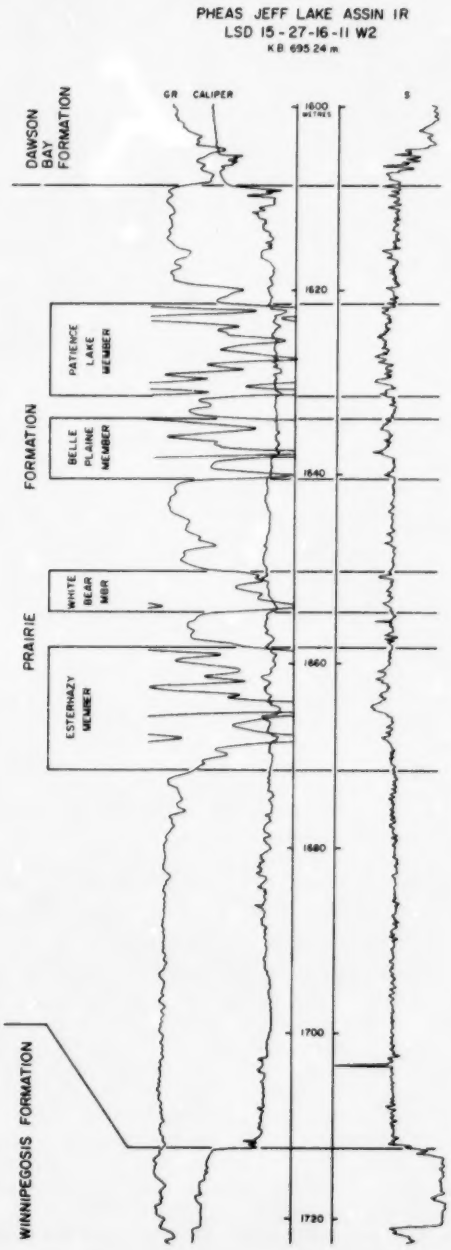

Figure 2 - Potash-bearing members of the Prairie Formation.

Discussion

This study indicates that most, if not all, of the carnallite occurring within the potash-bearing rocks in Saskatchewan is younger than either the sylvite or halite. Evidence for this includes (a) the occurrence of relict sylvite in carnallite crystals; (b) the marginal or centripetal replacement of sylvite by carnallite; (c) traces of cubic cleavage in the orthorhombic carnallite crystals, suggesting that they were formed by the replacement of sylvite or halite; (d) the presence of vertical, highly carnallitic stripes and bands in carnallite-rich zones; and (e) the more widespread occurrence of carnallite in the lower potash members than in the higher ones.

These observations suggest that the carnallite is the product of localized diagenetic changes brought about by magnesium-rich fluids migrating through potash-bearing rocks. These fluids partially or completely carnallitized the sylvite in these rocks. Vertical fractures and disturbed zones may have provided channelways for carnallitizing solutions and these liquids spread laterally and vertically into relatively porous zones (rock-controlled selectivity, Murray and Lucia, 1967).

As mentioned, the carnallite is more widespread in the lower members than in the higher members. However, carnallitization is

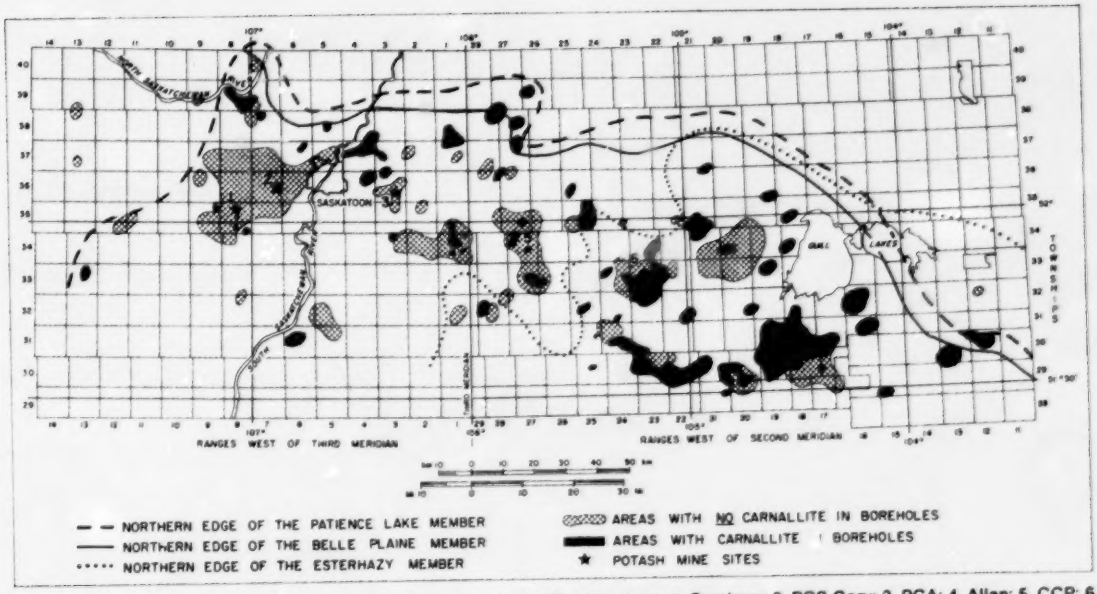
SASKATOON
RANGES WEST OF THIRD MERIDIAN
RANGES WEST OF SECOND MERIDIAN
TOWNSHIPS
NORTHERN EDGE OF THE PATIENCE LAKE MEMBER
NORTHERN EDGE OF THE BELLE PLAINE MEMBER
NORTHERN EDGE OF THE ESTERHAZY MEMBER
AREAS WITH NO CARNALLITE IN BOREHOLES
AREAS WITH CARNALLITE IN BOREHOLES
POTASH MINE SITES

Figure 3 - Distribution of carnallite in the Saskatoon mining district. Potash mines: 1, Cominco; 2, PCS Cory; 3, PCA; 4, Allan; 5, CCP; 6, PCS Lanigan.

more disseminated in the Esterhazy Member and overlying potash beds contain higher grade masses of carnallite. The only partial carnallitization of sylvite in the Esterhazy Member was probably the result of a low permeability in the sediments of this member during the process of carnallitization. On the other hand, the complete or near-complete carnallitization of sylvite above the Esterhazy Member was probably due to a much higher permeability in the sediments.

Highly argillaceous halite, 2 to 6 m thick and occurring immediately above the Esterhazy Member, indicates a certain change in the physicochemical conditions of the depositional environment. Precipitation of the salts was probably interrupted periodically and the sediments may have been occasionally subaerially exposed. Even a slight decrease in temperature could have changed the highly saline fluids within the sediments of the Esterhazy Member to a saturated brine from which salt would have been precipitated. As a result of this additional precipitation within these sediments, the already existing halite and sylvite crystals grew larger and at the same time the porosity and permeability of the sediments were gradually reduced by crystal growth. This process was likely responsible for the larger size of the salt crystals within the Esterhazy Member and also for the relatively low permeability of these sediments at the time of carnallitization. Carnallitization presumably took place soon after precipitation of the Prairie Evaporite when permeability was still high in the sediments, except for the salts in the Esterhazy Member which were subjected to the process described above.

The more widespread occurrence of the carnallitized orebodies in the lower potash members strongly suggests an upward flow of carnallitizing fluids before they spread laterally. Many of the structurally disturbed zones are believed to be coincident with Winnipegosis reefal mounds below the Prairie Evaporite. This relationship appears to be the result of a partial dissolution of the salt by water flowing through Winnipegosis mounds and consequent collapse and fracturing. The presence of magnesium-rich waters is essential for the process of carnallitization. The most likely source of magnesium is the Winnipegosis carbonates. The common occurrence of eogenetic and mesogenetic dolomites in the Winnipegosis Formation is convincing evidence for the presence of magnesium-rich fluids within these carbonates. Another possible source of magnesium is clay minerals occurring within the Prairie Evaporite and in the underlying strata. Magnesium could also have been derived from primary precipitates such as carnallite and bischofite. Dissolution of these highly soluble minerals could have provided magnesium for carnallitization. However, the author favours the Winnipegosis as the main source of these fluids.

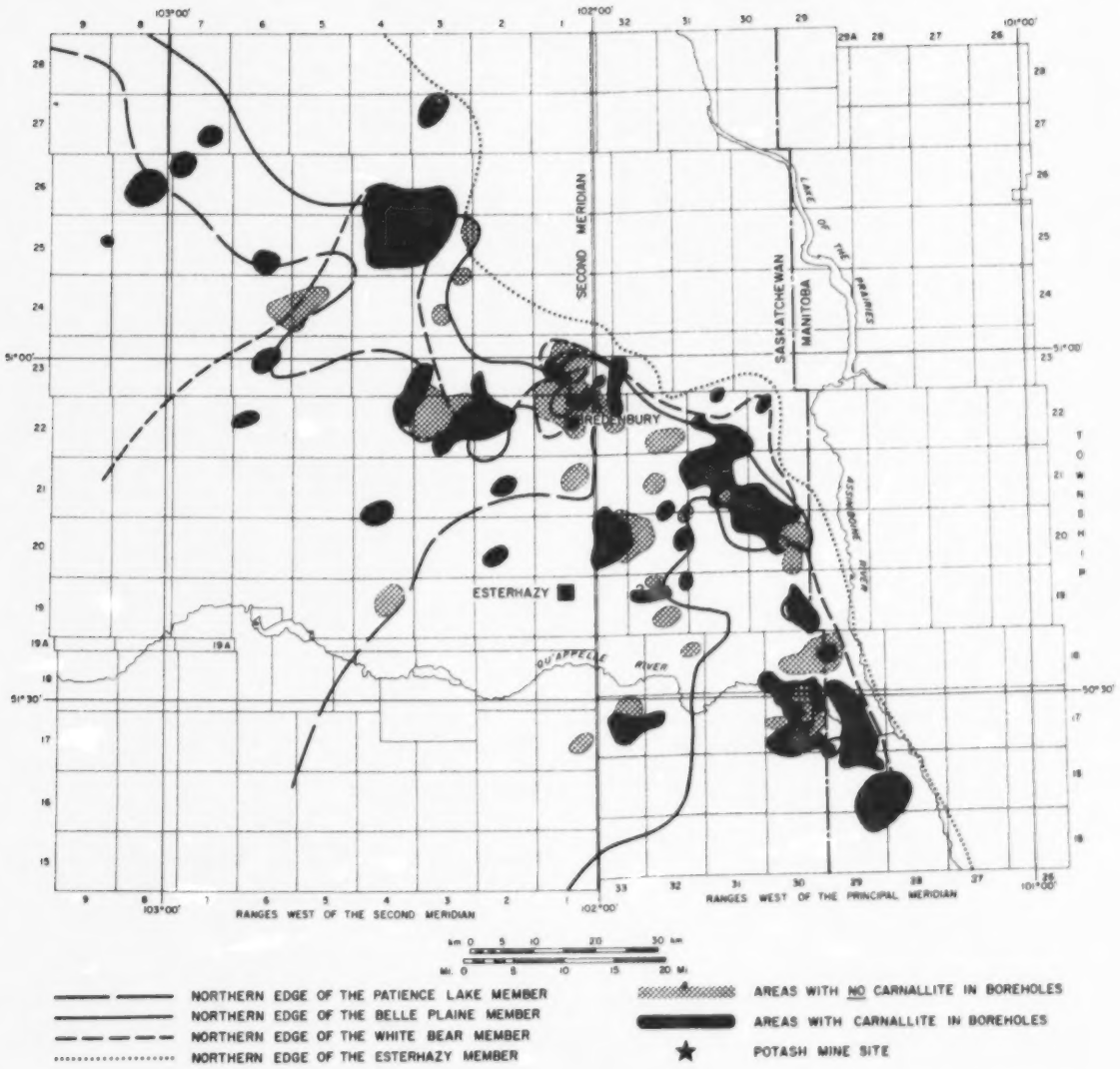
SECOND MERIDIAN
SASKATCHEWAN
MANITOBA
LAKE OF THE PRAIRIES
ASSINIBOINE RIVER
ESTERHAZY
QU'APPELLE RIVER
RANGES WEST OF THE SECOND MERIDIAN
RANGES WEST OF THE PRINCIPAL MERIDIAN
NORTHERN EDGE OF THE PATIENCE LAKE MEMBER
NORTHERN EDGE OF THE BELLE PLAINE MEMBER
NORTHERN EDGE OF THE WHITE BEAR MEMBER
NORTHERN EDGE OF THE ESTERHAZY MEMBER
AREAS WITH NO CARNALLITE IN BOREHOLES
AREAS WITH CARNALLITE IN BOREHOLES
POTASH MINE SITE

Figure 4 - Distribution of carnallite in the Esterhazy-Rocanville mining district. Potash mines: 1, IMCC K_1; 2, IMCC K_2; 3, PCS Rocanville.

The magnesium content of the carnallite is 8.75 percent but at present carnallite is not mined for the purpose of extracting magnesium. However, considering the expanding world market for magnesium and magnesium compounds, the vast carnallite reserves in Saskatchewan deserve attention. Magnesium is used in many fields of industry in structural and nonstructural metals. It has many desirable characteristics, such as strength, lightness, damping capacity, thermal and electrical properties, and the ability to be formed and joined. The greatest abundance of the carnallite occurs in the Belle Plaine Member. This member is carnallitized in many localities, particularly in the area around Quill Lakes. The average thickness of this high-carnallite ore (up to 90 percent carnallite) is about 14 m in this area. In addition to the carnallite in the Belle Plain Member, the lower part of the Patience Lake Member is also commonly carnallitized. Solution mining appears to be the most feasible method of extraction. Utilization of the by-products, such as potassium and chlorine, would make magnesium production in Saskatchewan more attractive.

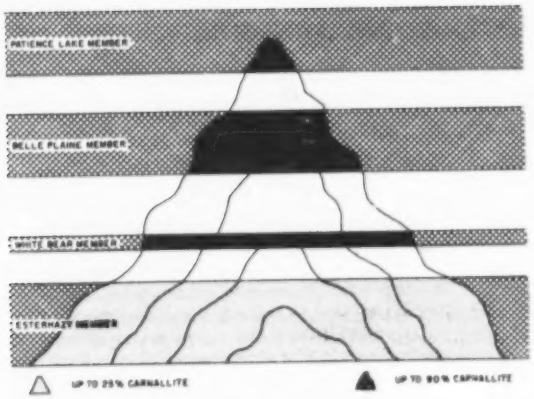

Figure 5 - Model of carnallitization.

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Valyashko, M.G. (1956): Geochemistry of bromine in the processes of salt deposition and the use of the bromine content as a genetic and prospecting criterion; Geochemistry, v. 6, p. 570-589.

ABSTRACTS OF SASKATCHEWAN ENERGY AND MINES REPORTS

The following are abstracts of reports by the Saskatchewan Geological Survey published during the past year or scheduled to be released before December 31, 1983:

Broughton, P.L. (1982): Coal resources of southern Saskatchewan: catalogue of Late Cretaceous - Cenozoic formation and coal seam boundaries; Saskatchewan Energy and Mines, Open File Report OF 82-5 (6 microfiche).

This microfiche catalogue of Late Cretaceous and Early Cenozoic formation and coal seam boundaries in southern Saskatchewan was compiled for use in conjunction with Saskatchewan Mineral Resources Report 209 "Coal Resources of Southern Saskatchewan: A Model for Evaluation Methodology." The catalogue presents detailed stratigraphic data on coal seams which, in Report 209, were combined as "net coal" according to specific economic criteria. Also included are data from areas beyond the arbitrary map boundaries established in Part II of Report 209.

Well locations are listed according to the surveyed municipal land location system by quarter of a legal subdivision (LSD), section (SEC), township (TWP), range (RGE) and west of meridian (MER). Locations are also defined in the Universal Transverse Mercator System. All thicknesses and depths are in metres and all elevations are in metres above mean sea level.

Johnston, W.G.Q. (1983): Geology of the Southend area; Saskatchewan Energy and Mines, Open File Report OF 82-4, 151 p.

The supracrustal rocks of the Southend area (NTS 64D-6), one of abundant outcrop, are largely metasediments and pelitic biotite paragneisses. Conformable with these gneisses are meta-arkose bands, many with sillimanite partings and/or quartz-sillimanite nodules. The meta-arkoses appear more extensively granitized than the other gneisses. In the central and western parts of the area, ultramafic to intermediate volcanics (largely intermediate tuffs) attain thicknesses of over 1.5 km and appear conformable with and younger than paragneisses. Calc-silicate gneisses are an important component of some volcanic bands. Pillow lavas were identified in several localities and, although deformed, pillows in a flow overlying a conglomerate in the north-central part of the area clearly indicate the flow top. The ultramafic flows form almost continuous markers trending northeasterly across the northwestern part of the area and continuing easterly along the northern boundary of the area's east half and far beyond.

Southeastward, from the layered rock's northwest limit where original depositional features are recognizable, deformation and metamorphism increase in intensity and the relatively high grade Kisseynew Gneisses underlie some of the eastern and southern parts of the area. Within the Kisseynew Gneisses are two distinct groups of rocks of differing age which are herein designated the Upper and Lower Kisseynew Gneisses. A large granodiorite occurs in the northwestern part of the area and a granodiorite complex underlies much of the central and southeastern parts.

A westerly striking diabase dike occurs in the extreme southwestern part of the area. Abundant undeformed Cretaceous shale clasts (possibly Albian and/or Cenomanian) occur in the drift south of Deep Bay (Reindeer Lake), much of which is underlain by these shales, 165 km north of similar Cretaceous rocks in the plains. The youngest consolidated rocks are small tillite remnants adhering to Precambrian outcrops. This tillite may be Illinoian and extensive weathering in it indicates an interglacial or interstadial period possibly Sangamon. A map of the Quaternary geology at the same scale as the bedrock geology map (1:63,360) accompanies the report.

Folds plunge northeastward throughout the area, which is apparently near the eastern limit of north-trending faults belonging to the Tabbernor Lake Fault system which extends many miles to the north and also southward beyond the Canadian Shield. Northeast-trending faults are also present and most abundant west of the main Tabbernor Lake Fault.

Geochemical sampling was carried out in conjunction with the geological mapping. Location maps for 813 bedrock samples (one sample per 0.95 km^2) and 806 overburden samples (one sample per 0.94 km^2) accompany the report. Locations, descriptions and Co, Ni, Cu, Zn and Pb values for the bedrock and soil samples are given in Appendices A and B respectively.

The area has been covered by airborne radiometric, magnetic and electromagnetic surveys. Electromagnetic anomalies have been checked by ground geophysical surveys and 58 short diamond-drill holes which intersected graphite and/or small amounts of barren iron sulphides. Sparse chalcopyrite was observed along a belt west of Reindeer Lake.

Extensive bulk sampling was carried out in 1977 on a graphite prospect east of the northern extremity of the Southend Indian Reservation.

Lewry, J.F. (in press): Geology of an area around Kohn Lake; Saskatchewan Energy and Mines, Report 222, 20 p.

The area around Kohn Lake forms part of the Mudjatik Lithostructural Domain. Metasediments of the Wollaston Group occur as northeast-trending belts in the south and east of the area. Metasediments of the Many Islands belt, much lower in metamorphic grade than those of the Wollaston Group, form the nose of a synform in the extreme north. Most of the area is underlain by migmatites, felsic and granitoid gneisses, and later massive leucogranite and biotite granite, termed collectively the "infrastructural complex". This complex underlies the Many Islands belt and is interfolded with the Wollaston Group. Two major fold/foliation-forming episodes, accompanied and outlasted by uppermost amphibolite to granulite facies metamorphism, are recognized in the Wollaston Group and the infrastructural complex. The Many Islands belt occupies the core of a regional-scale synform and is interpreted as high-level superstructure. Restricted northeast-trending cataclasite/mylonite zones and later north-south faulting are also recognized.

Preferred mineral exploration targets are considered to be the Wollaston Group and the junction zone between the Many Islands belt and infrastructural complex.

McDougall, F.H., Watters, B.R. and Parslow G.R. (1983): Mineral occurrences in the Precambrian of NTS areas 63K and 63L; Saskatchewan Energy and Mines, Open File Report OF 82-6, 492 p.

This open file report, compiled under a contract with the University of Regina, comprises all non-confidential data, up to March 1979, located in Saskatchewan in NTS areas 63-K-5,-12,-13, and 63-L-8 to -16. Data are incorporated in deposit descriptions and geophysical descriptions numbered sequentially per map sheet, and illustrated in abbreviated form on the scale of 1:50,000 (taken from a 1:125,000 scale compilation map prepared by R. Macdonald).

Two maps are presented for each NTS area. The first is a compilation of data on the size, type, mineralogy and commodity of mineral deposits, while the second shows the locations of geophysical surveys. Data on sand and gravel deposits in the area are not included.

Some assessment files do not describe deposit mineralogy — consequently relevant map data are likewise incomplete. All assay information is listed in deposit descriptions; however, only those commodities that returned positive assay results are shown on the maps. Since pyrite and/or pyrrhotite are virtually obiquitous in the volcanic rocks of the region, some minor barren sulphide occurrences are not included.

Parslow, G.R. and Stolz, H. (1983): Evaluation of techniques for assessing the uranium potential of lake-covered areas; Saskatchewan Energy and Mines, Open File Report OF 79-1, 102 p.

Over the period 1975-78, various field and laboratory techniques for exploring water-covered areas were evaluated. Sampling methodology, radon 222 analysis in the field, water quality measurements, uranium in water and sediments, Ni, Cu, Zn and Co in sediments, volume effects versus LOI data, disequilibrium measurements, bottom radioactivity and resistivity, and water depths were all studied. It is concluded that sample collection can be accomplished rapidly, that sediment data were easier to interpret than water data, and that the important parameters controlling interpretation of elemental distributions are: pH, volume changes in sediment and disequilibrium effects in the uranium decay series. In addition, it is recommended that multi-element analysis of sediments is undertaken.

Bottom radioactivity can be mapped quickly and efficiently and is a good method for following radioactive boulder fans from land into the water. In addition, this survey technique can generate its own anomalies within the lake and successfully map the limits of underwater radioactive outcrop. The resistivity results yield a qualitative picture of the nature of the bottom (ooze, sand, boulders) and help to ensure that the probe remains in contact with the bottom.

Finally, the geochemical results indicate that, although anomalous lakes can be defined, no method is known at present which will directly relate anomalous areas in a lake to mineralization.

Scott, B.P. (1982): Geology of the Laird Lake (west) area; Saskatchewan Energy and Mines, Report 196, 10 p.

Supracrustal rocks in the area consist of hornblende gneiss, biotite gneiss and meta-arkose. Tonalite gneiss, quartz diorite and biotite migmatite are partly anatectic.

The occurrence of hornblende-garnet and cordierite-anthophyllite indicate metamorphic conditions of amphibolite facies grade. Relict granulite facies grade is indicated by the rare occurrence of hypersthene in norite veins and hornblende gneiss.

The dominant structures are isoclinal north-trending folds which interfere with an east-west fold set near the southern boundary. Most small folds plunge gently to the north-northeast with axial planes dipping vertically to steeply east. A few folds plunge at moderate angles in the southwest quadrant.

Traces of chalcopyrite occur in hornblende gneiss near the Tabbernor Lake Fault in the southeast corner of the area.

The following 1:250,000 scale Compilation Bedrock Geology Series maps are scheduled to be released before December 31, 1983. These full colour maps summarize the bedrock geology in the Precambrian Shield area, and include geological annotations and references to source material.

Macdonald, R. and Thomas, M.W. (1983): Compilation bedrock geology, Reindeer Lake North, NTS area 64E; Saskatchewan Energy and Mines, Report 232 (1:250,000 scale map with marginal notes).

Ray, G.E. (1983): Compilation bedrock geology, Foster Lake, NTS area 74A; Saskatchewan Energy and Mines, Report 228 (1:250,000 scale map with marginal notes).

Ray, G.E. (1983): Compilation bedrock geology, Geikie River, NTS area 74H; Saskatchewan Energy and Mines, Report 229 (1:250,000 scale map with marginal notes).

Thomas, M.W. (1983): Compilation bedrock geology, Wollaston Lake, NTS area 64L; Saskatchewan Energy and Mines, Report 211 (1:250,000 scale map with marginal notes).

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Senior assistants who assisted project leaders in the field are named on the accompanying maps. Full acknowledgment for assistance in the field is expected to be made in the final reports, where applicable.

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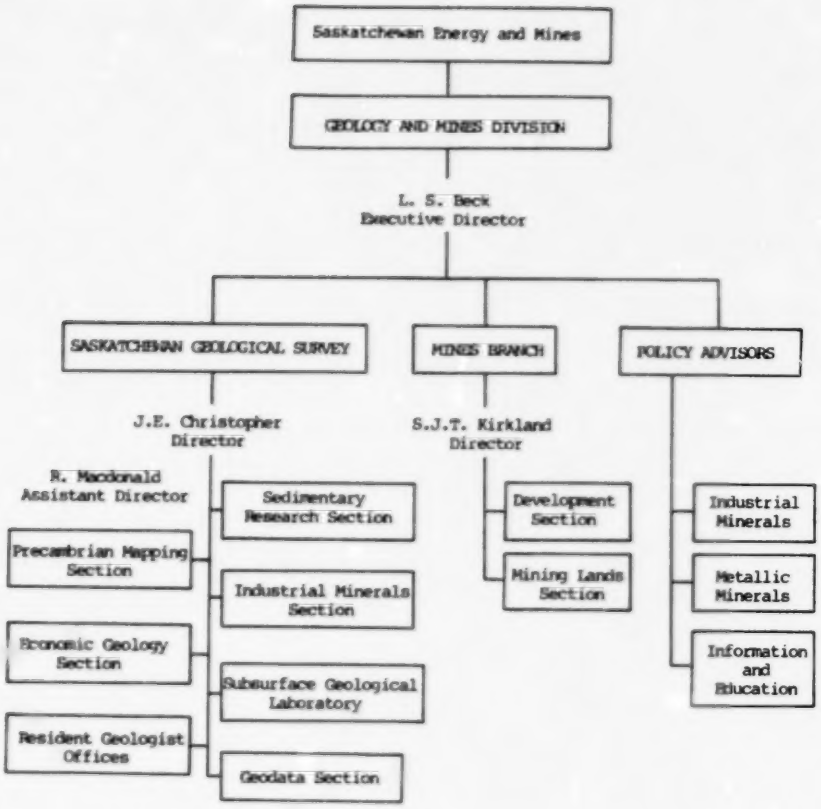
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